PB-222 710

GAINESVILLE COMPOST PLANT

FINAL REPORT ON A SOLID WASTE MANAGEMENT DEMONSTRATION
VOLUME I, GENERAL REPORT. VOLUME II, TECHNICAL
EVALUATION

GAINESVILLE MUNICIPAL WASTE CONVERSION AUTHORITY, INC.

PREPARED FOR
OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS

1973

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VOLUME I, GENERAL REPORT

VOLUME II, TECHNICAL EVALUATION

This final report (SW-21d) on work performed under Federal solid waste management demonstration grant no. D01-UI-00030, to the Gainesville Municipal Waste Conversion Authority, was prepared jointly by the GAINESVILLE MUNICIPAL WASTE CONVERSION AUTHORITY, INC., *and* ENVIRONMENTAL ENGINEERING, INC., *and is reproduced as received from the grantee.*

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This report summarizes a technical and economic evaluation of the Gainesville, Florida, Compost Plant which operated from 1968 to 1971. The plant had a capacity of 150 tons of municipal solid waste per day. Paper was hand separated and iron was electromagnetically separated. Raw or digested sewage sludges were mixed with the solid waste prior to the 6-day aerobic digestion process. The compost product was not marketable, which upset the anticipated economic picture. The local citizens became disenchanted with the ability of the plant to meet their solid waste disposal needs and the plant was subsequently closed. The project's interim reports referenced as Nos. 4, 5, and 6 have not been published and are not available to the public. The information in those reports has been summarized in this final report.

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An environmental protection publication (SW-21d) in the solid waste management series.

CONCLUSIONS

1. A decision to utilize any composting system as a means of waste treatment must depend on assured markets for compost and salvage materials.
2. The plant as originally designed was inadequate in the following respects:
    a. Belt widths of all conveyors were too narrow.
    b. No dust control system and inadequate floor drainage.
    c. The receiving area under roof was too small.
    d. The receiving area should not have a ramp approach.
    e. The welding shop was poorly ventilated and the resulting fumes were a hazard to workers on the control console.
    f. The electric motors on both primary grinders were too small (600 h.p. is the minimum requirement).
    g. The refuse receiving and compost discharging activities both being located in the same area caused congestion.
    h. Inadequate space for curing compost.
    i. The picking platform was located too close to the primary shredder resulting in hazards from dust, noise, and projectiles.
    j. The feed mechanism of the Williams primary shredder was too low resulting in some refuse being projected out of the feed hopper.

    k. Facilities for mixing refuse with sewage sludge were inadequate.

3. Refuse can be composted with sewage sludge without any unmanageable problems.
4. The potential for composting quantities of refuse and sewage sludge derived from equivalent populations was shown.
5. Windrow curing of digested compost is necessary to insure compost stability in contemporary uses.
6. Storage of compost in large piles does not bring about curing.
7. Three days of digestion is probably sufficient time to kill most pathogenic microorganisms in waste which was subjected to the heat normally generated in the digesters.
8. Projected costs to make compost saleable to the small consumer show a poor economic outlook.
9. The present state-of-the-art of solid waste analysis is inadequate for effective process control and evaluation.
    a. There is no satisfactory method for the determination of putrescible matter in solid wastes.
    b. There is no method which is conclusive and convenient for the determination of the public health quality of compost or solid waste.
    c. Elaborate instrumentation is neither necessary nor

desirable for process control and evaluation of composting on an industrial scale.

10. The cost of composting is competitive with incineration.
11. Composting has a rightful place in contemporary solid waste management, but its full potential has yet to be manifested.

RECOMMENDATIONS

1. Land reclamation by the application of large quantities of crude grade compost should be investigated for the ultimate disposal of compost.
2. The investigation of composting should be continued with particular emphasis on salvage of waste components and other aspects of resource recycling and the supplementation of refuse with additional organic wastes.
3. Equipment should be developed for mixing of refuse and sewage sludge to assure maximum utilization of sludge.
4. The design and construction of future compost plants should take into consideration all means to overcome the shortcomings in plant design and operation manifested by this demonstration.

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I. INTRODUCTION

Refuse disposal has become an acute problem in the United States in recent years. The present per capita generation of refuse is about five pounds per day.* The urban sprawl has made the availability of low cost sanitary fill sites limited. Incineration has been relied on heavily in urban areas for many years, but creates severe air pollution problems and has a high operating cost. These disposal problems, together with the demand for increased agricultural production suggest the desirability of adopting a refuse reclamation procedure as a partial solution to both problems. High-rate composting in municipal plants offers the most potential return of the reclamation systems now available.

Composting has been practiced in Europe and Asia for centuries. In both areas intensive cultivation is practiced, which requires the maintenance of soil quality by adding as much organic matter to the soil as is possible. Thus, a ready market for compost exists. In this country, with extensive cultivation practice and a well established regime of chemical fertilization, compost has not found any appreciable market.

To date, most municipal composting operatins in the United States have ended in failure. The primary reason for this failure has been the attempt by the composters to approach composting as a profit-making operation without adequate support from the municipality in the form of dumping fees. Sufficient background has been developed to indicate that, with the current market for compost, this approach is totally impractical. Still, composting does offer the potential of a nuisance-free, medium cost refuse disposal system for municipal use, provided that the facilities are properly designed and operated, and that financing is adequate.

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*Note from the publisher, the U.S. Environmental Protection Agency: According to the 1968 national survey of community solid waste practices, conducted by the Federal solid waste management program, 5.3 pounds per person per day was the figure for wastes collected. The amount generated per capita was calculated to be over 10 pounds per day from residential, commercial, institutional, and industrial sources.

Few municipal and public health officials or consulting engineers will recommend composting as a means of municipal refuse disposal for many of the reasons just stated. It is desirable, then, to establish municipal scale composting facilities in sufficient numbers to obtain reliable technical and economic data on the construction and operating costs. These data will permit adequate public appraisal of this system of refuse disposal. Pilot plant operation will not suffice because, in the case of most pilot plants, no binding contract or responsibility for maintaining a day-to-day disposal facility exists. Thus, if mechanical difficulties or market depressions occur, the plant can be "temporarily" turned off and the refuse diverted to other locations until either the facility is operable or the market improves. For general acceptance of refuse composting in the United States it will be necessary for compost operators to provide a continuous nuisance-free municipal service. This can best be accomplished through the construction and operation of demonstration compost plants.

The Metro Waste Conversion System was developed as a new approach to the solid waste disposal problem, treating solid waste as a natural resource to be recycled into channels of commerce, agriculture, and trade. The system was first developed as a pilot plant in Largo, Florida, which had a daily capacity of about 40 tons per day. The operation of this plant for two years suggested technical and economic feasibility of composting on a larger scale. The plant at Gainesville was built on the basis of experience gained in Largo and was intended to broadly demonstrate technical and economic feasibility by satisfactory and continuous operation. Another plant of the Largo type was constructed in Houston, Texas, and put into operation in January, 1967. It has a daily input capacity of 360 tons.

Prior to the construction of the Gainesville plant, the local communities had been using poorly managed methods for the ultimate disposal of solid wastes. The City of Gainesville burned yard trash and tree trimmings at a dump and buried refuse and garbage in a landfill. The County of Alachua intermittently used the city landfill or their own designated dumps. The University of Florida managed their wastes by means of a transfer station and a three acre sanitary landfill, which was rapidly being filled to capacity. Thus, there was a strong local need for an alternative and more satisfactory process for the ultimate disposal of solid wastes.

In addition, the University of Florida, Departments of Environmental Engineering and Soils was interested in cooperating with the then proposed compost plant in furtherance of their teaching and research obligations. The Soils Department relied on the plant as a source of compost for their research on soil amendments. The Environmental Engineering Department assigned an entomology student to a fly and pest control study at the plant. In addition, classes made frequent field trips to the plant.

To be an eligible recipient of Federal funds, the Gainesville Municipal Waste Conversion Authority, Inc. was formed under a not-for-profit certificate of incorporation issued by the Secretary of State of Florida. Purposes of the Authority as set forth in its Certificate of Incorporation include the disposal of garbage, trash and sewage wasted generated in the City of Gainesville, other communities, and educational and other public institutions, and to pursue a program on continuing testing, experimenting and study to develop the most efficient, sanitary and nuisance-free methods, processes, equipment, procedures and techniques to accomplish effective, sanitary composting processes of municipal waste and producing a compost end product of maximum benefit and value for agricultural and horticultural uses and applications; also, to carry on testing, experimenting and study programs to demonstrate effective and satisfactory methods, standards and principles for efficient operation of compost plants.

The Gainesville Municipal Waste Conversion Authority was governed by a board of seven trustees. One trustee represented each of the three Public Participants in the program - the City of Gainesville, the County of Alachua, and the University of Florida. A fourth trustee was designated by the first three trustees to represent the Public Participants in general. The three remaining trustees represented Metropolitan Waste Conversion Corporation, whose process was demonstrated.

Two-thirds of the plant construction costs were derived from the U. S. Public Health Service. The remaining one-third of construction costs were derived from the sale of first mortgage revenue bonds in the amount of $530,000. These bonds yielding 6 1/2 percent interest were sold through Francis I. duPont and Company. The bonds mature at the rate of $25,000 per year from 1970 - 1990. Funds to repay the principal and interest were derived from the sale of compost and salvaged materials. Salvaged paper provided the most funds. It was sold in the Jacksonville area for a price ranging from $9 - 19 per ton. It was initially anticipated that the sale of ferrous metals consisting mainly of tin cans would yield appreciable money. This did not materialize, however, because no local market exists. Shipment of ferrous metals to Birmingham, Alabama, the closest market, prohibited economic metal recycling. The sale of compost yielded some money, but it was much less than anticipated

II. OBJECTIVES

The primary objective was to demonstrate the reliability, suitability and technical and economic feasibility of the Metropolitan system, as an example of a high-rate composting system, for the treatment of refuse and raw domestic sewage sludge.

Other objectives were:

1. To demonstrate effective occupational health, sanitation, and pest control practices suitable for composting processes in particular and solid waste management in general.

2. To demonstrate the production of a compost product which is nuisance-free and meets or exceeds public health requirements, even though it was derived from refuse supplemented with raw sewage sludge.

3. To demonstrate the quality of equipment utilized in the Metropolitan composting system including effectiveness, efficiency, economy, and required maintenance.

4. To demonstrate the capability of a high-rate composting plant for treating refuse supplemented with raw sewage sludge in the same proportion that both wastes are produced by a municipality.

5. To provide an effective teaching and research facility to be used by the University of Florida.

6. To provide compost of various qualities for research into its effect on soils and plants.

III. PLANT DESIGN

A. DESIGN FACTORS

The design of the Gainesville plant was based on experience obtained at the Metropolitan Waste Conversion Corporation pilot plant located at Largo, Florida. The design of a large commercial plant located in Houston, Texas was also based on the Largo pilot plant. The construction of the Houston plant preceeded the Gainesville plant and the additional experience gained in building the former facility was passed on to the latter one. Composting is accomplished in batch loaded, forceably aerated, mechanically agitated digesters to encourage high-rate waste stabilization. The system is designed to accept all refuse normally collected by municipalities with the exception of bulky and demolition wastes. There are provisions for removing salvage materials and non-compostable materials from the waste stream and for further processing of them. The compostable fraction of waste is shredded in two stages, moistened with water, sewage sludge or other appropriate liquid waste and subsequently digested to a partially stable, nuisance-free material commonly called compost, which may be used as a soil conditioner. The system incorporates modern, efficient materials-handling processes throughout. The Gainesville plant was designed to compost refuse and sewage sludge derived from a community having a population of about 70,000.

Based on these general objectives, specific design criteria were adopted as follows:

1. Overall capacity: 150 tons per day.
2. Operating capacity. 20 tons per hour.
3. Paper extraction: hand separated and mechanically baled.
4. Metal extraction: combination of hand sort, ballistic and electromagnetic separation.
5. Digester particle size: approximately one inch by one inch.
6. Moisture control: electronic sensing and pump control.
7. Digestion period: six days.
8. Digester agitation schedule: variable, one to three times during digestion.
9. Digester aeration schedule: complete flexibility as to length of cycle and duration of aeration per cycle.
10. Digester temperature and gas content: measuring and recording equipment adequate for evaluation, processing and research purposes.
11. Final grind particle size: typical size 1/4", adequate for both application in basic "raw" condition and for further processing in blending, enriching and granulating processes.
12. Curing period: 8 weeks or longer in conical shaped piles.

B. TIME SCHEDULE

Approximately eight months were required from the time of notice of the grant award for completing the organization of the Authority, selecting a project director, completing the financing of the non-grant portion of the cost of the plant, completing the detailed designing of the plant, taking construction bids, and the letting of contracts. Construction was begun about March 1, 1967. It took approximately 12 months for construction, shake-down and testing of the plant. While the plant was still in the course of design, Metropolitan completed the construction of the Houston plant and placed this plant in regular commercial operation. After observing this plant in operation, considerable important information was developed from actual experience and observation and, where the plant layout and detailed design of the Gainesville project could benefit, advantage of this additional experience and knowledge was taken.

IV. DETAILED DESCRIPTION OF PLANT

A. SITE

The plant is located on a 5-acre tract of land which was provided by the City of Gainesville. This tract is a part of the sewage treatment plant site of the City, and is located immediately across a small stream from the sewage treatment plant itself. A substantial expansion of the sewage treatment plant has been completed recently, and a sludge line has been constructed from the sewage treatment plant for pumping thickened sludge to the compost plant for disposal in the composting process. (Figure 1, Vicinity Map)

B. BUILDINGS

The plant consists of three separate buildings. A small building, 72 ft. x 32 ft., houses the office, a two room laboratory, and a general-purpose classroom-conference-meeting room. (Figure 2, Office Building)

The main plant building, about 30,000 square feet, contains most of the plant equipment, including that for receiving, processing, digesting and final grinding of the composted refuse. The Bulk Storage Building is 90 feet long by 76 feet wide by 20 feet high, with a sloping shed roof. This building covers the compost truck loading area, and also an area where some compost can be stockpiled for curing, and where some finished compost can be stored.

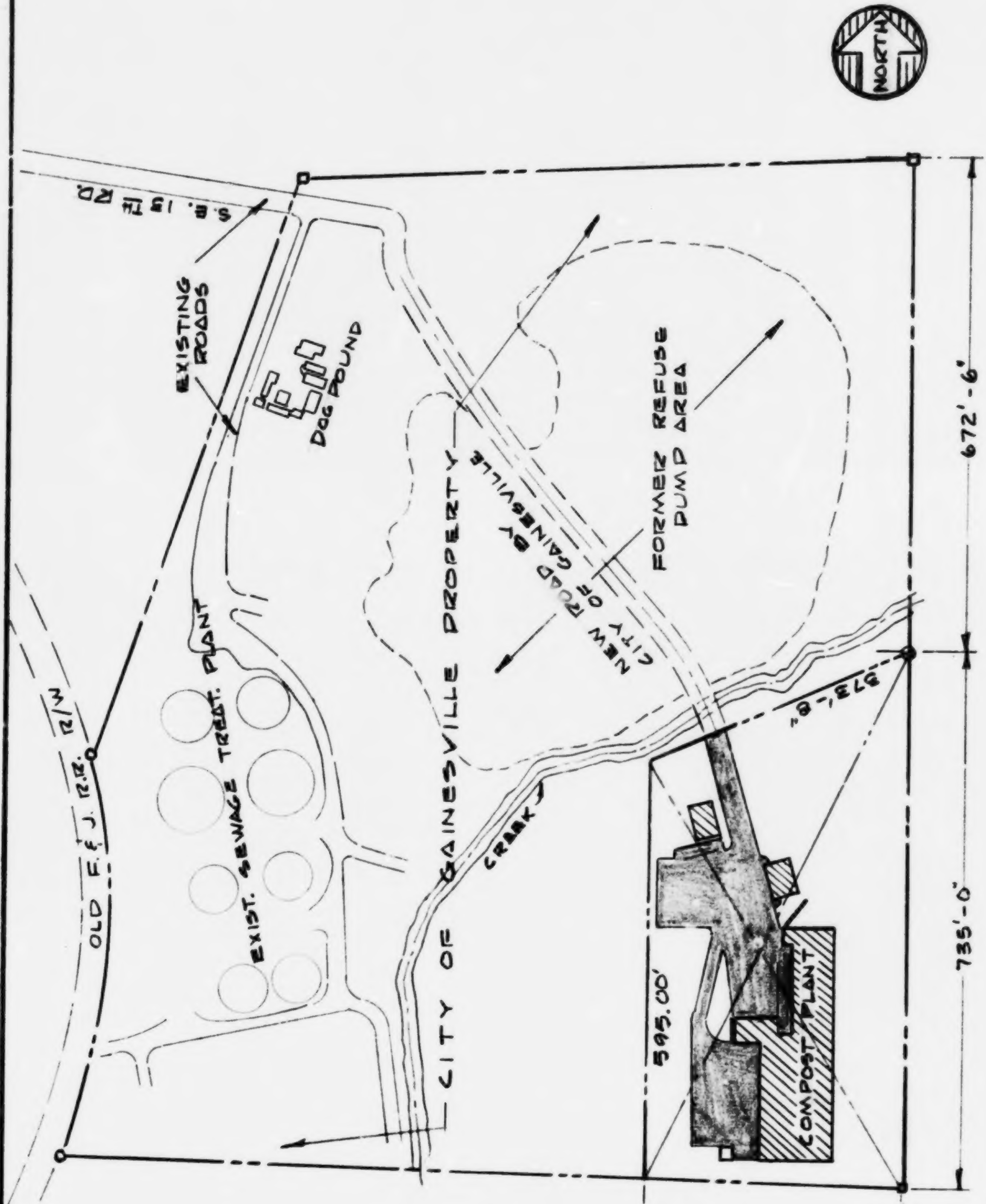

NORTH
S.E. 13TH RD.
EXISTING ROADS
DOG POUND
FORMER REFUSE DUMP AREA
NEW ROAD BY CITY OF GAINESVILLE
CITY OF GAINESVILLE PROPERTY
EXIST. SEWAGE TREAT. PLANT
OLD F.E.J. R.R. R/W
CREEK
COMPOST PLANT
595.00'
373'-8"
672'-6"
735'-0"
350'-0"

FIG. 1

VICINITY MAP
SCALE = 1" = 200'

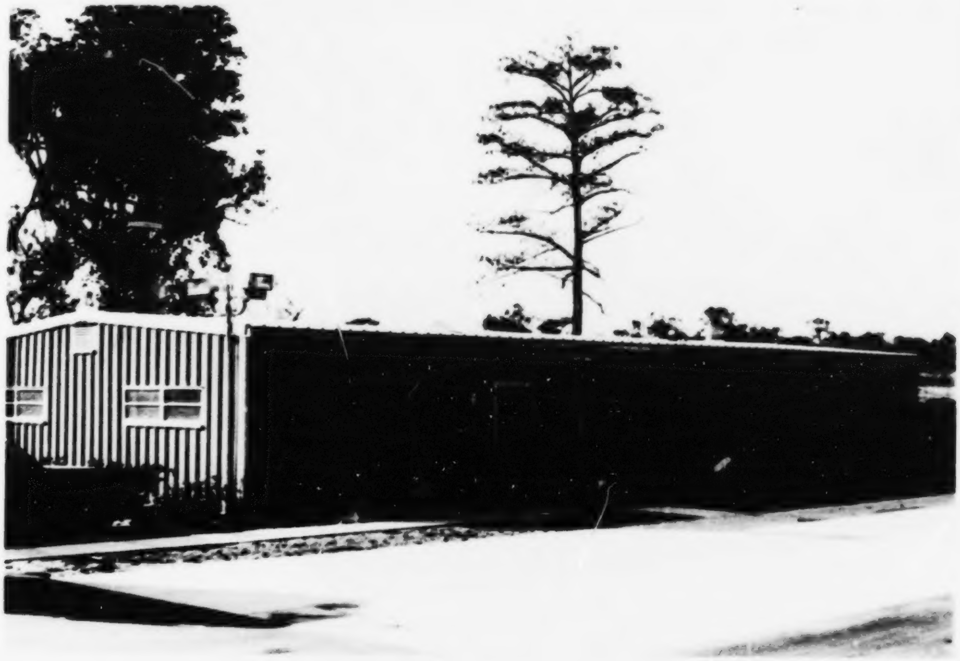


FIGURE 2

Office Building

All buildings are essentially standard, industrial-type steel buildings. The office-laboratory building has an attractive masonry front. Figure 3 shows the floorplan and dimensions of the office building. Figure 4 shows the dimensions and layout of the main plant building. Figures 5 and 6 (original and revised) show the flow of material through the plant, including all the various handling and processing systems.

C. RECEIVING SYSTEM

1. Truck Scale (Figure 7)

The scale is a Toledo Model 2781 motor truck scale of 50-ton capacity having a 60' x 10' platform and the following equipment:

a. Electronic dial and weight printer with nine banks of selective numbering devices.

b. Card reader to receive pre-punched plastic truck identification cards and giving a signal of 4 digits for truck identification and 5 digits for tare weight to the weight printer and adding machine.

c. Adding machine equipped to provide in one operation the gross weight, subtract tare weight to give net weight, and having the capability of maintaining accumulated net subtotals, and to total and clear at the will of the operator. The adding machine can be operated together with the card reader and the weight printer.

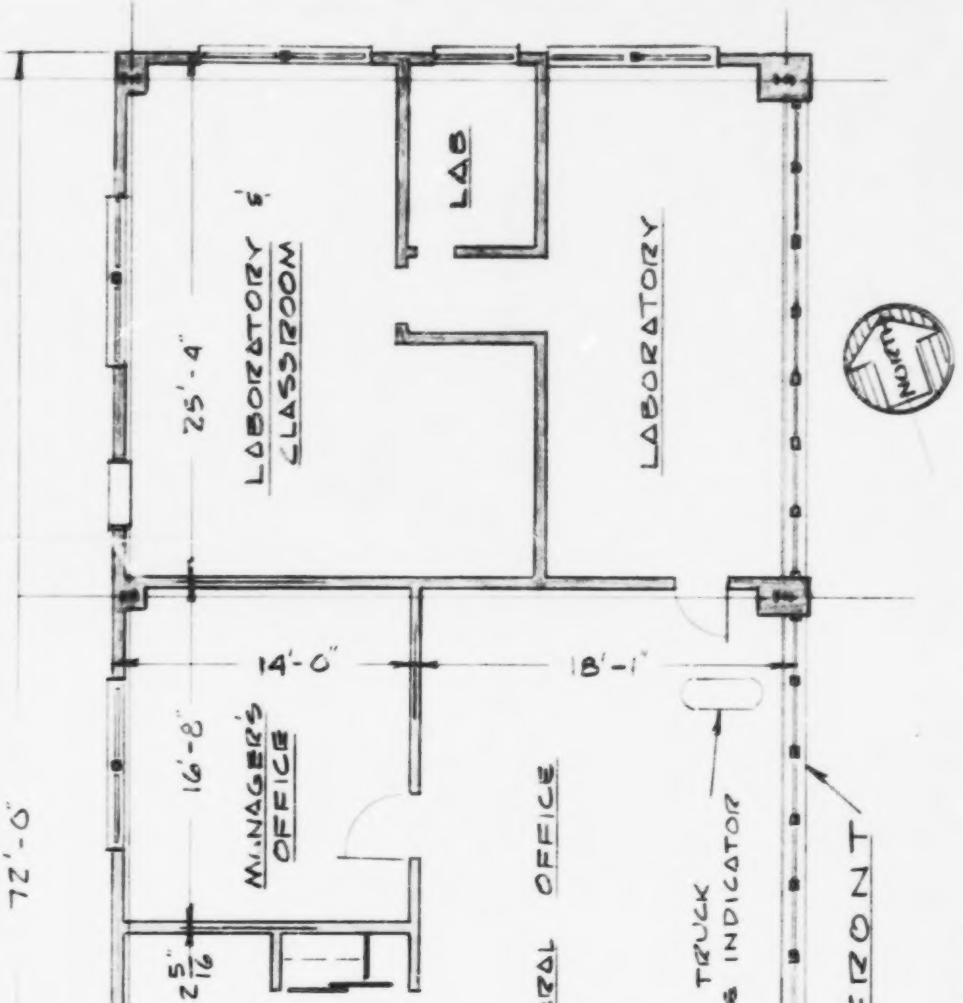
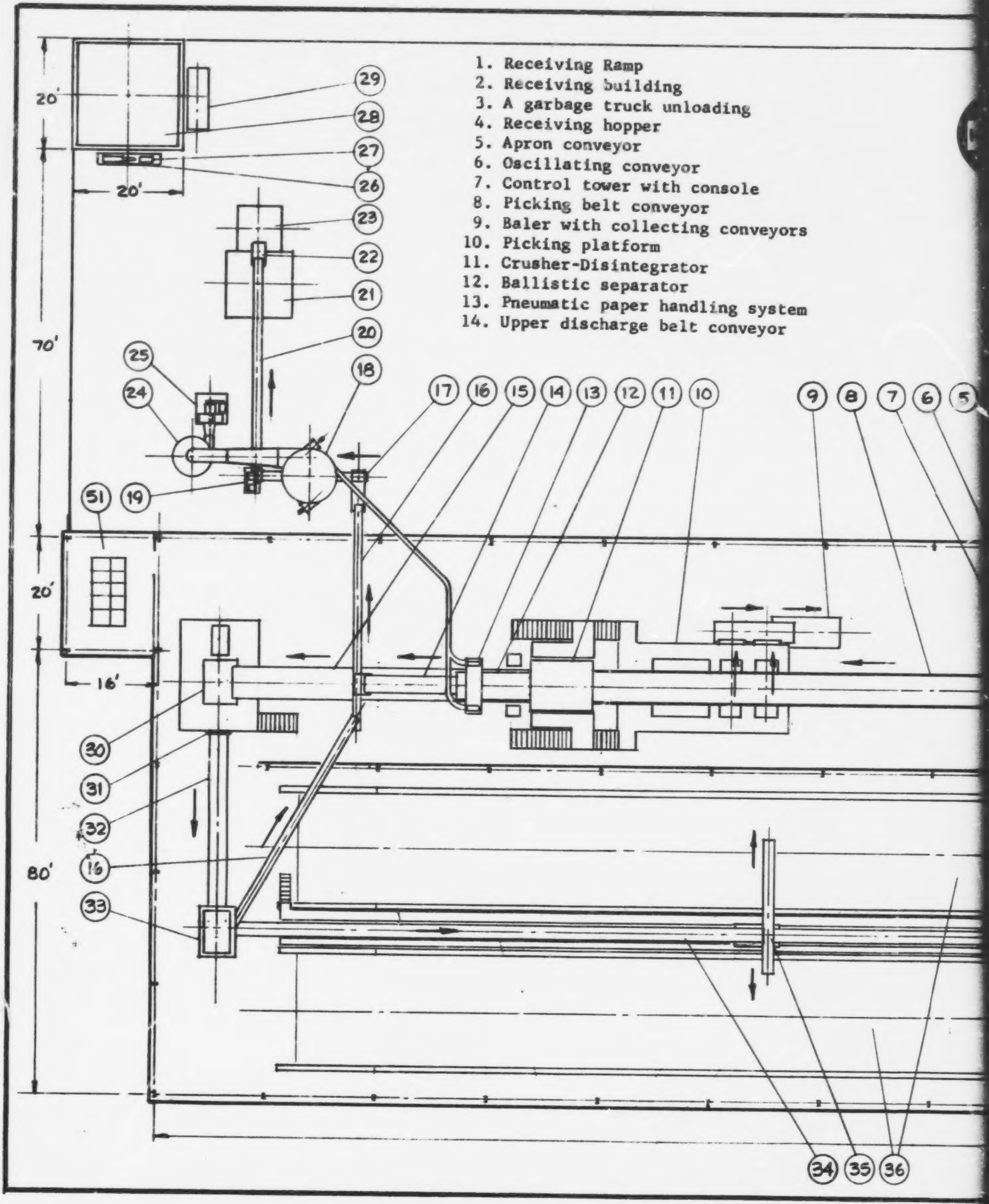
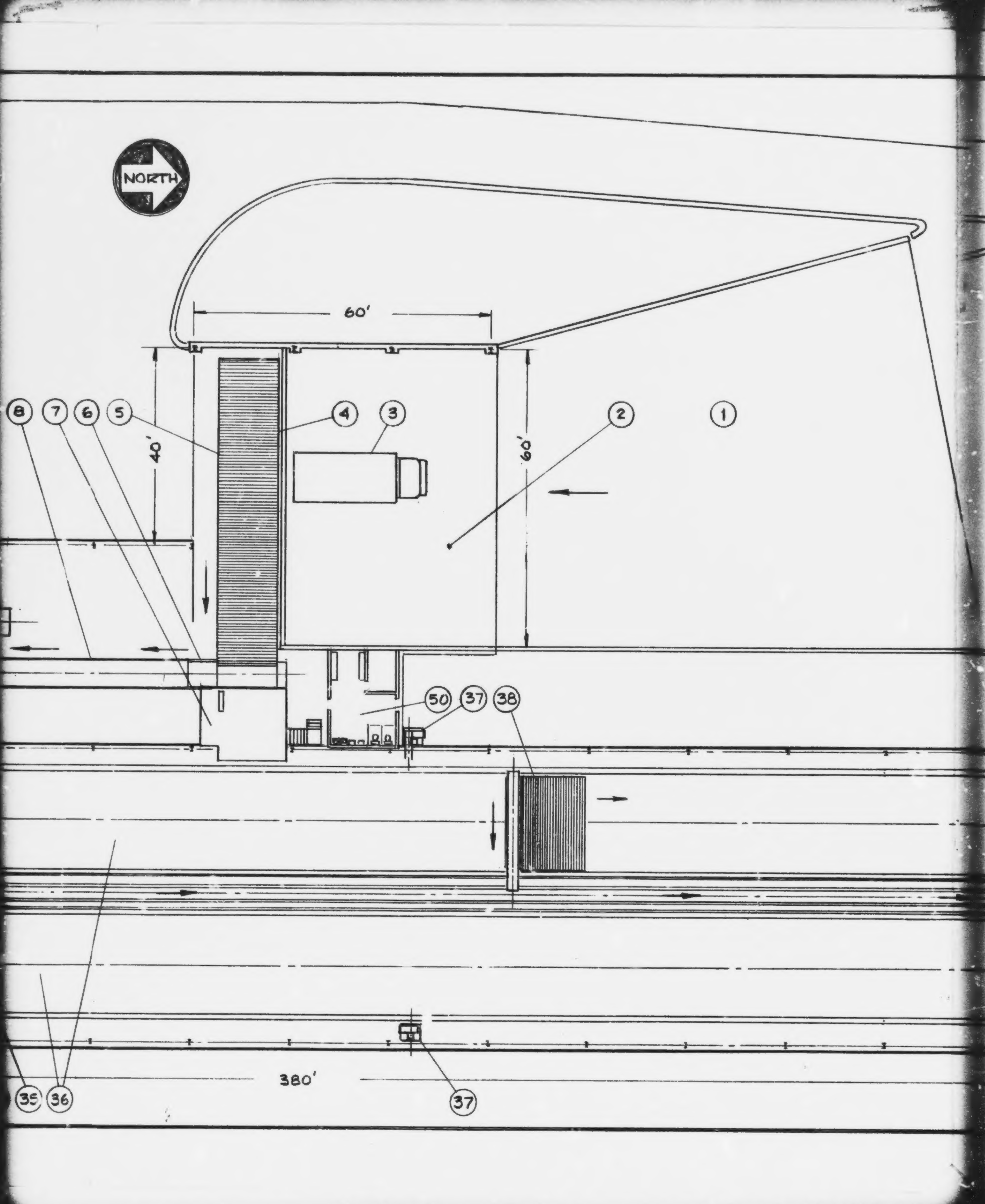

72'-0"
25'-4"
LABORATORY & CLASSROOM
LAB
LABORATORY
NORTH
14'-0"
18'-1"
16'-8"
MANAGER'S OFFICE
GENERAL OFFICE
TRUCK SCALE INDICATOR
FRONT
7'-2 5/16"
7'-0"
WOMEN
MEN
15'-9 11/16"
CONFERENCE AND CLASSROOM
32'-2 1/2"

FIG. 3

OFFICE FLOOR PLAN


20'
20'
70'
20'
16'
80'
29
28
27
26
23
22
21
20
25
24
18
17
16
15
14
13
12
11
10
9
8
7
6
5
51
19
30
31
32
16
33
34
35
36

1. Receiving Ramp
2. Receiving building
3. A garbage truck unloading
4. Receiving hopper
5. Apron conveyor
6. Oscillating conveyor
7. Control tower with console
8. Picking belt conveyor
9. Baler with collecting conveyors
10. Picking platform
11. Crusher-Disintegrator
12. Ballistic separator
13. Pneumatic paper handling system
14. Upper discharge belt conveyor


NORTH

15. Lower discharge belt conveyor
16. Can Conveyor
17. Woven metal belt
18. Burner
19. Metal pelletizer
20. Metal pellet conveyor
21. Ferrous metal hopper
22. Magnetic separator
23. Non-ferrous metal
24. Air heater exhaust scrubber
25. Scrubber exhaust blower
26. Sludge pump
27. Sludge aeration blower
28. Sludge tank
29. Diesel oil storage tank
30. Secondary grinder
31. Sludge mixing screws
32. Cross conveyor
33. Magnetic separator
34. Tripper unloading belt
35. Tripper with unloading shuttle conveyor
36. Digesters
37. Digester aeration blowers
38. Agiloader w/unloading shuttle conveyor
39. Agiloader transfer car rails
40. Digester unloading conveyor
41. Agiloader transfer car
42. Regrind loading conveyor
43. Regrind distributing screw conveyor
44. Regrind mill feeder screw conveyors(2)
45. Regrind mills (2)
46. Regrind overflow screw conveyor
47. Regrind discharge screw conveyor
48. Stockpiling belt conveyor
49. Storage building w/truck loading ramp
50. Lavatory and showers
51. Electrical switchgear room

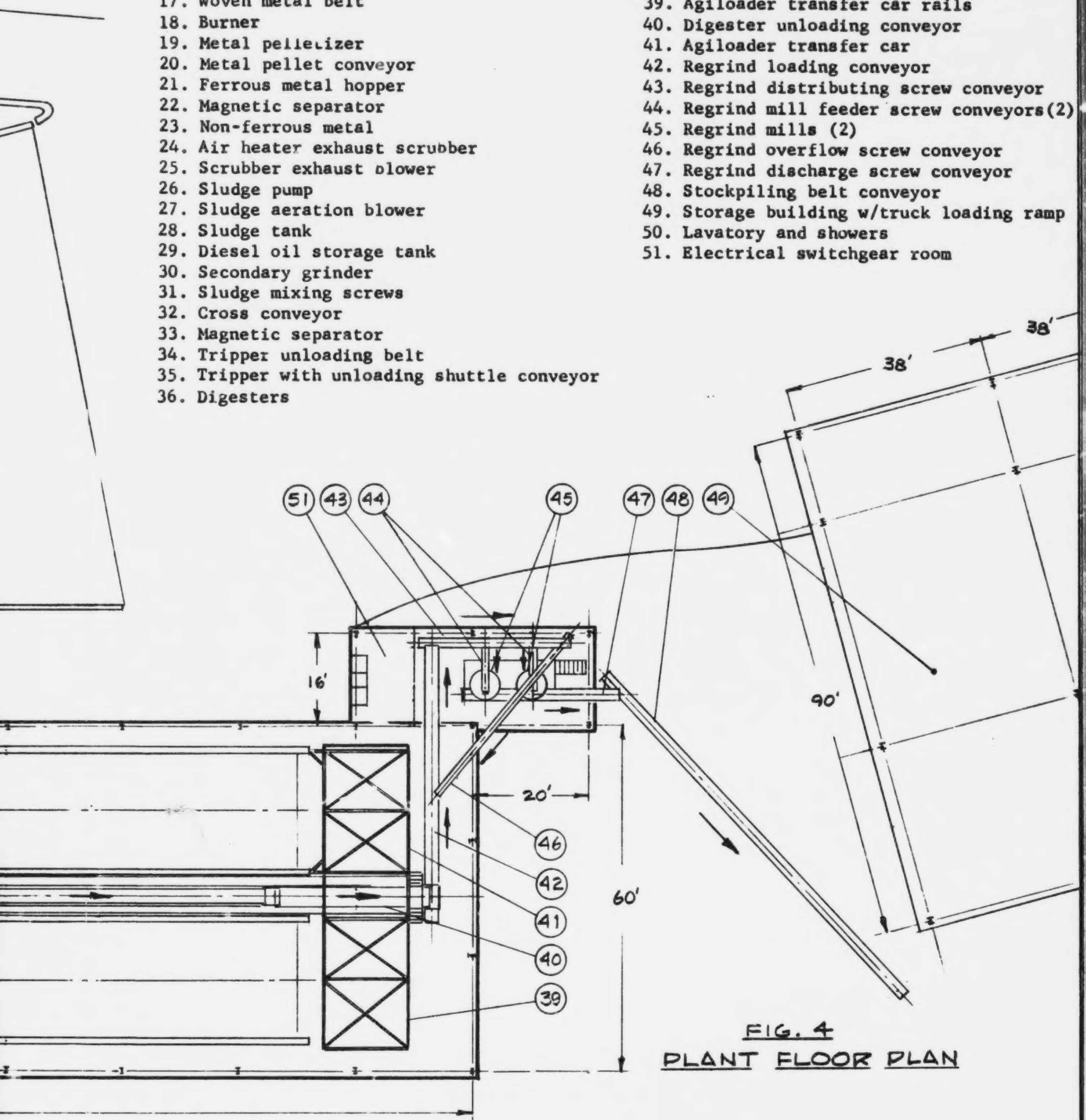
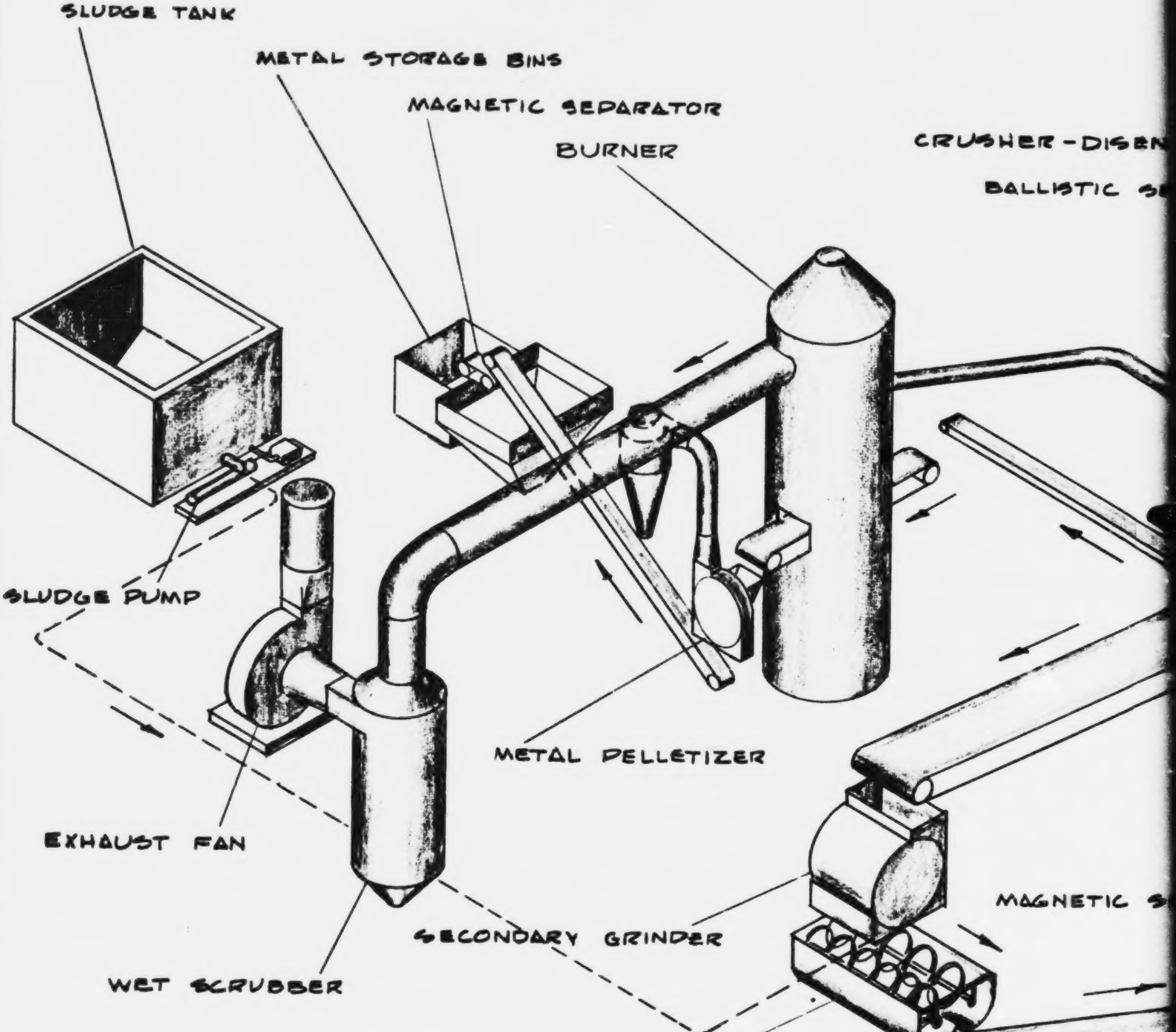
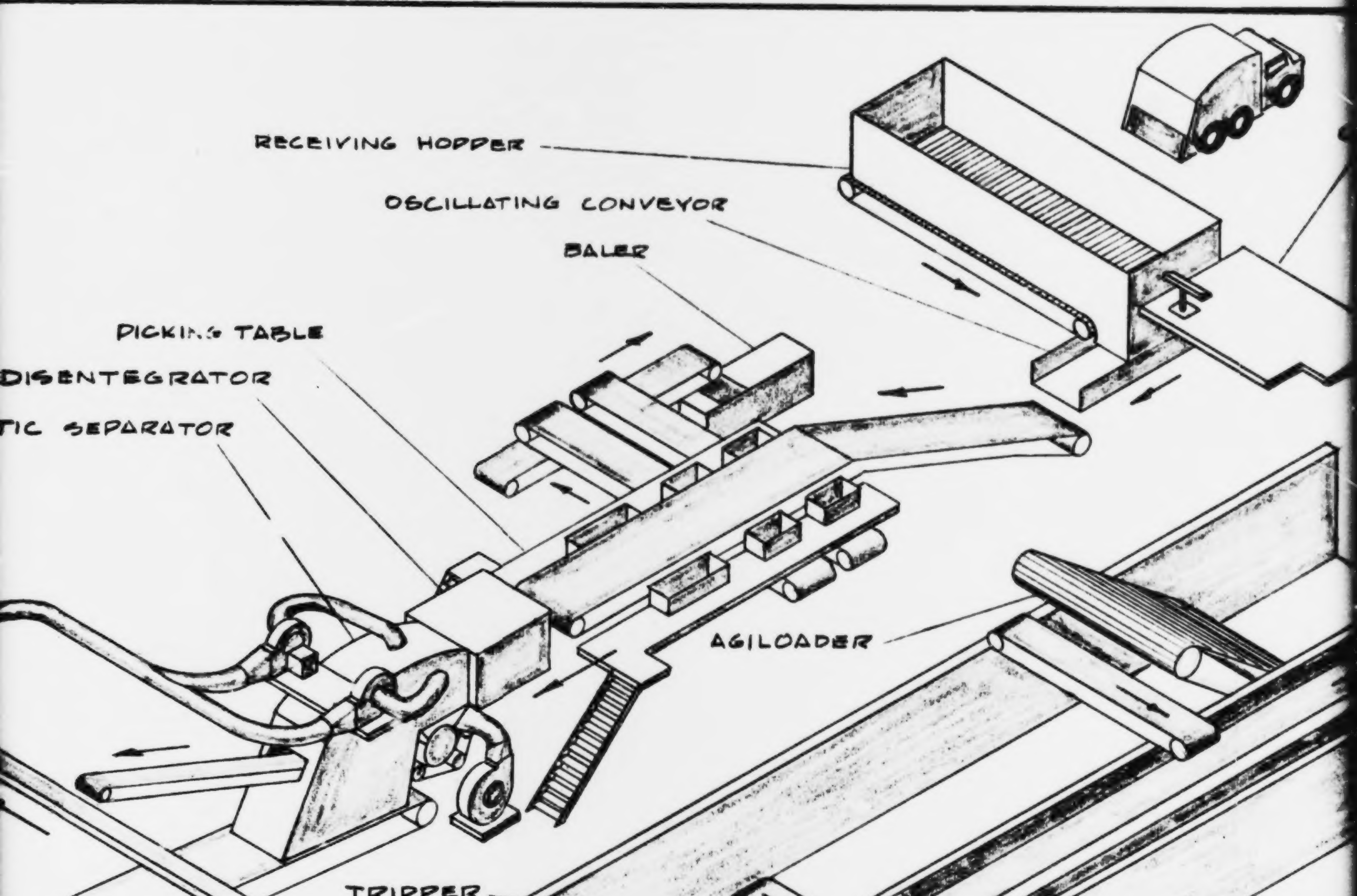


FIG. 4
PLANT FLOOR PLAN


SLUDGE TANK
METAL STORAGE BINS
MAGNETIC SEPARATOR
BURNER
CRUSHER-DISEN
BALLISTIC S
SLUDGE PUMP
METAL PELLETIZER
EXHAUST FAN
MAGNETIC S
SECONDARY GRINDER
WET SCRUBBER
MIXING SCREWS


RECEIVING HOPPER
OSCILLATING CONVEYOR
BALER
PICKING TABLE
DISENTEGRATOR
TIC SEPARATOR
AGILOADER
TRIPPER
STIC SEPARATOR
AER
DIGESTER

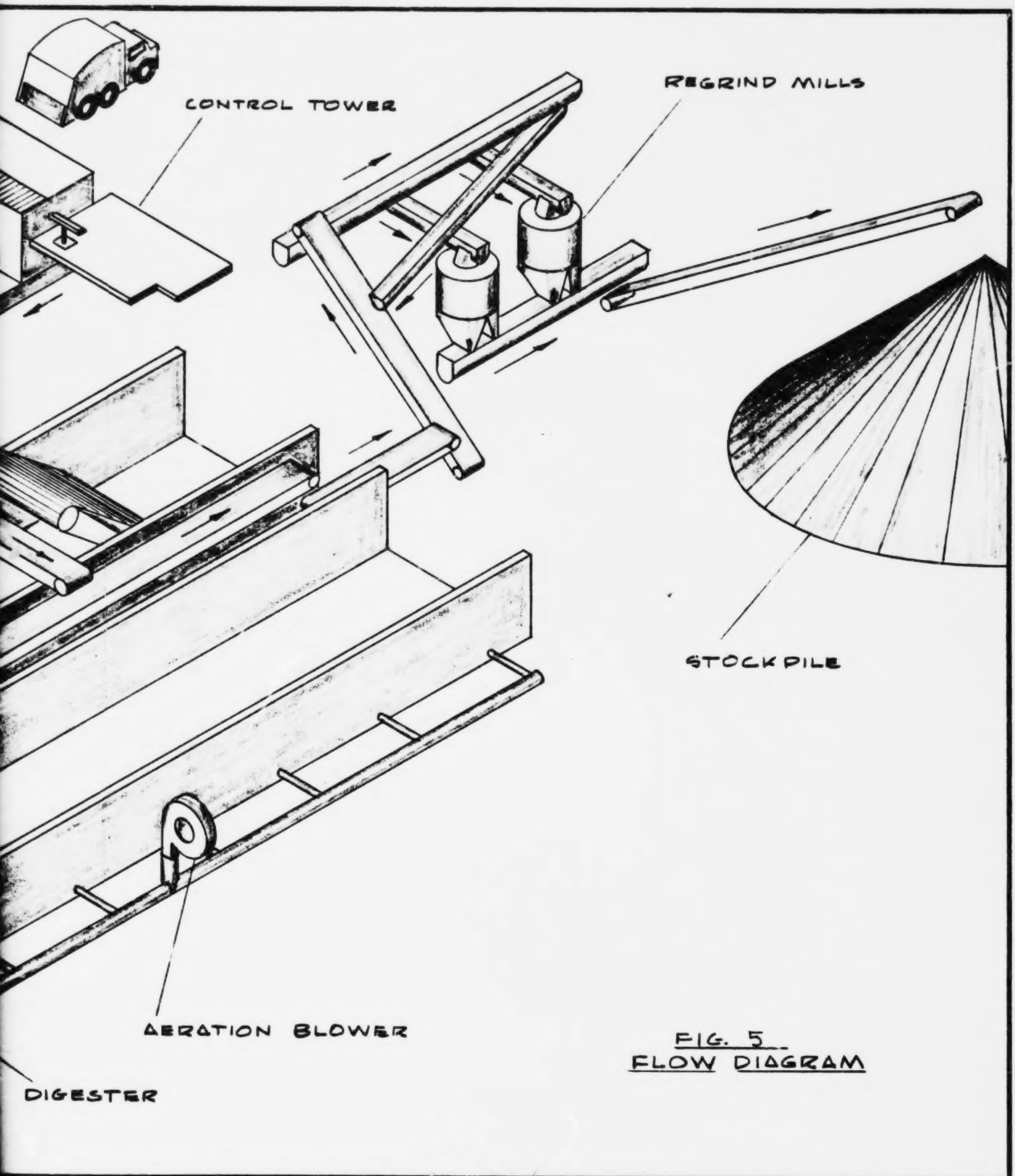
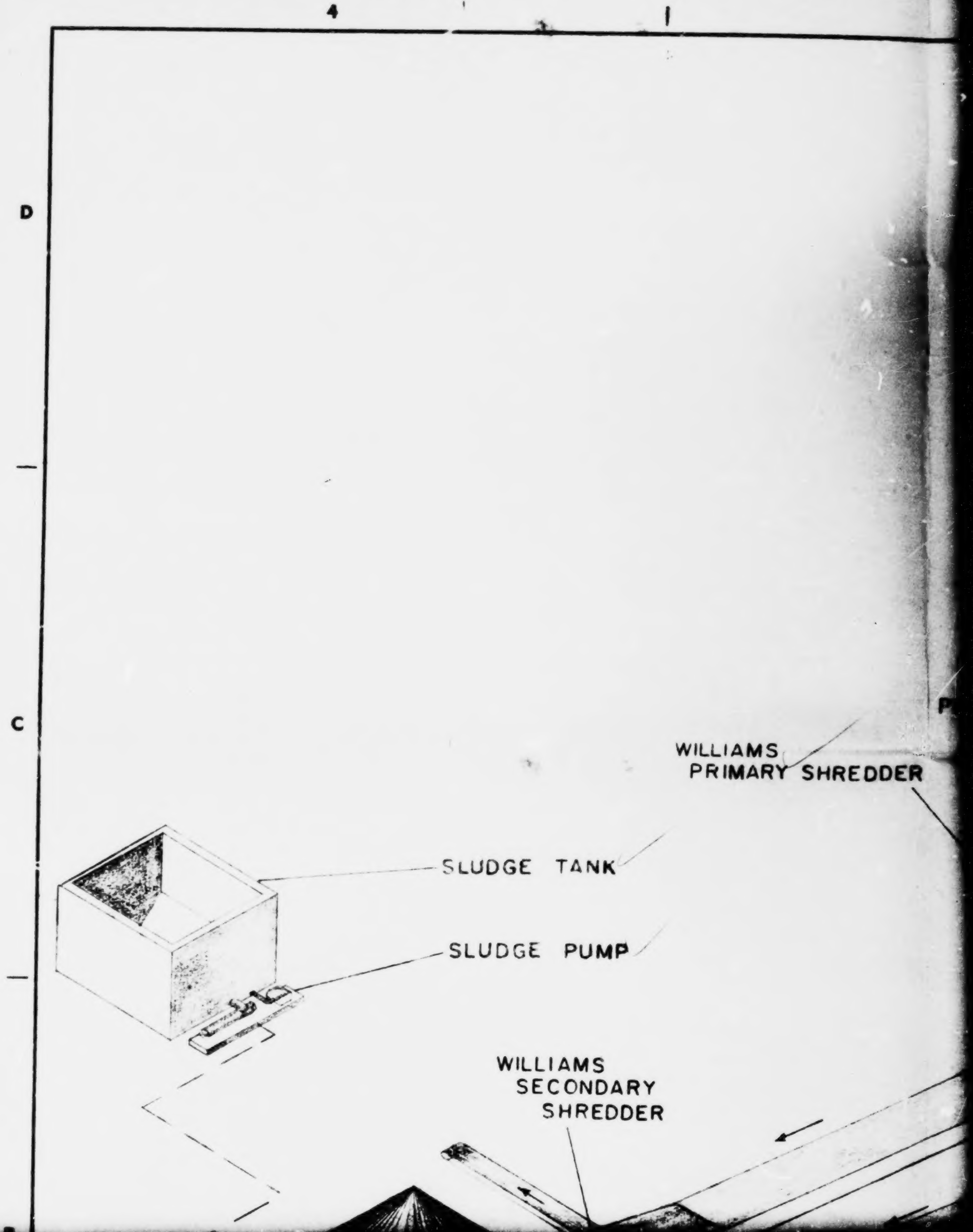
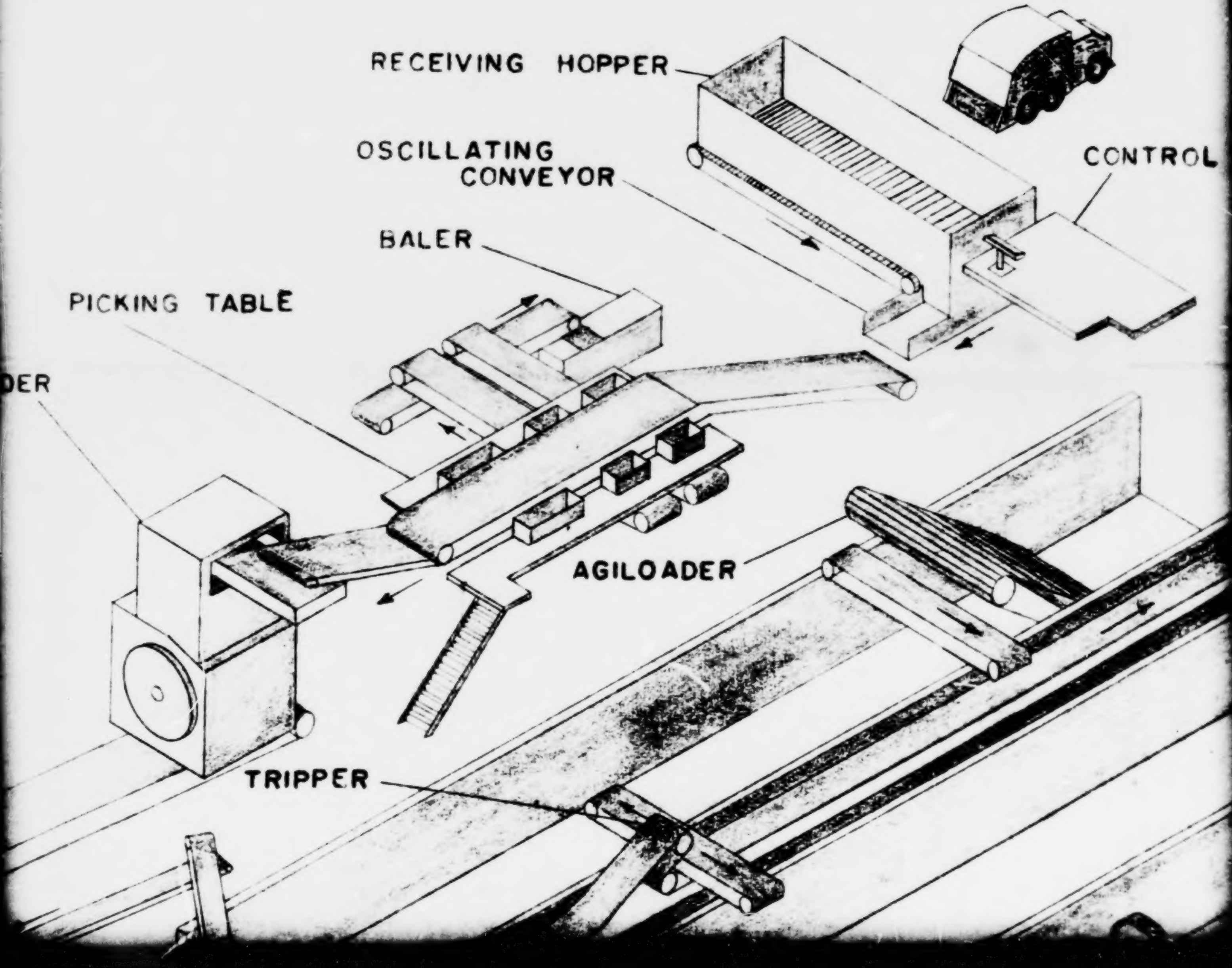

CONTROL TOWER
REGRIND MILLS
STOCKPILE
AERATION BLOWER
DIGESTER

FIG. 5
FLOW DIAGRAM


4
D
C
WILLIAMS
PRIMARY SHREDDER
SLUDGE TANK
SLUDGE PUMP
WILLIAMS
SECONDARY
SHREDDER

3 1 2


RECEIVING HOPPER
OSCILLATING CONVEYOR
CONTROL
BALER
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AGILOADER
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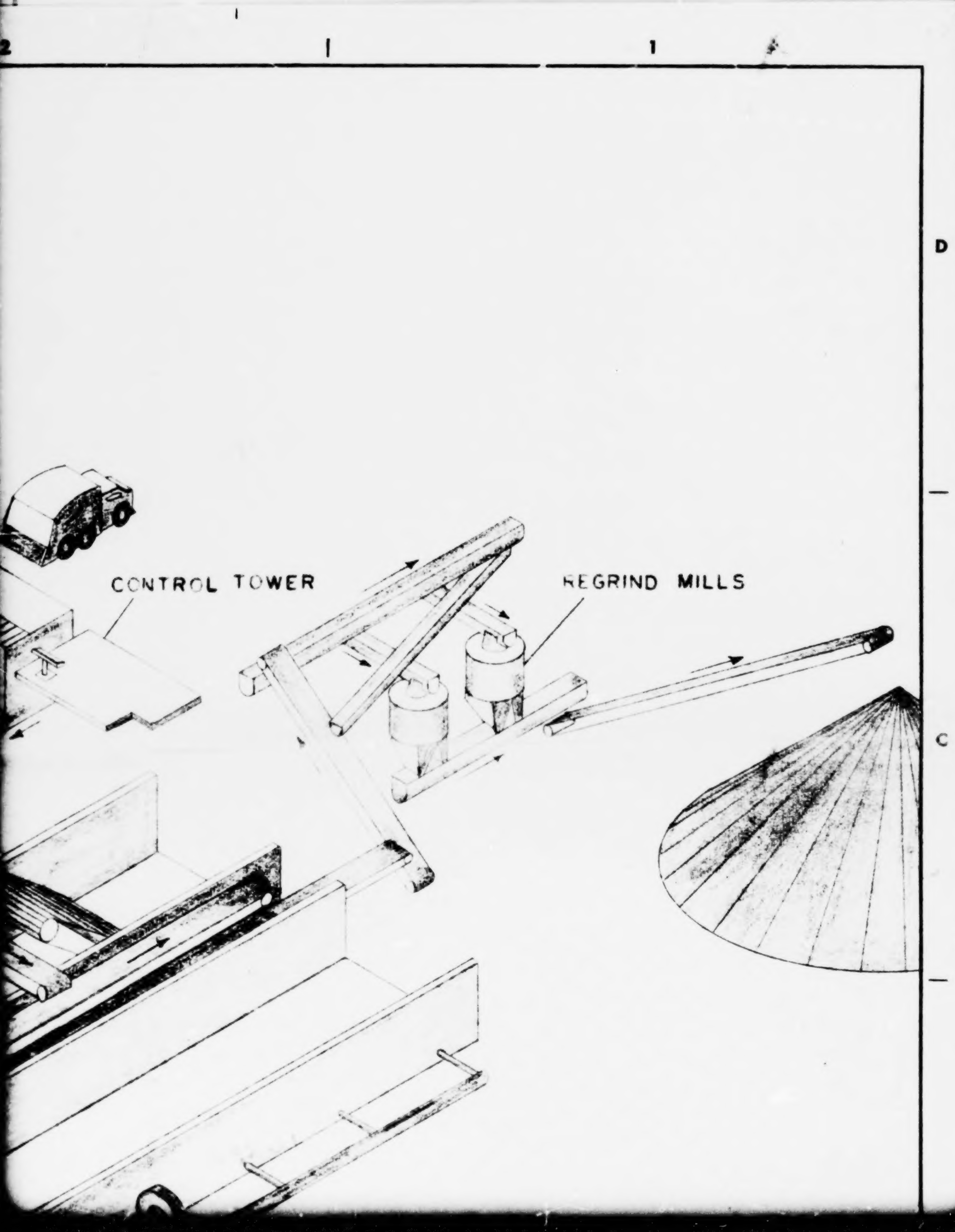
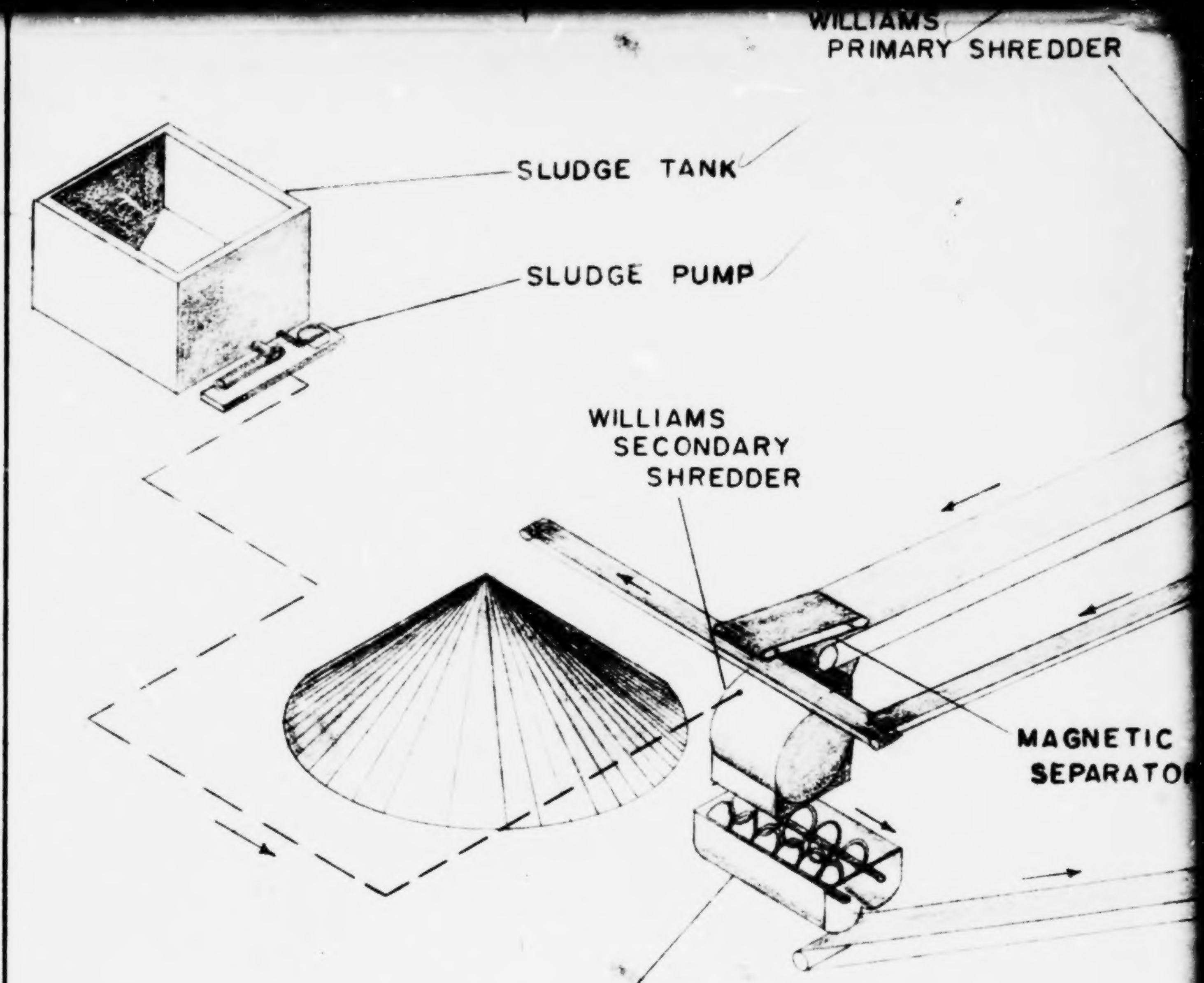

2
1
D
C
CONTROL TOWER
REGRIND MILLS


WILLIAMS
PRIMARY SHREDDER
SLUDGE TANK
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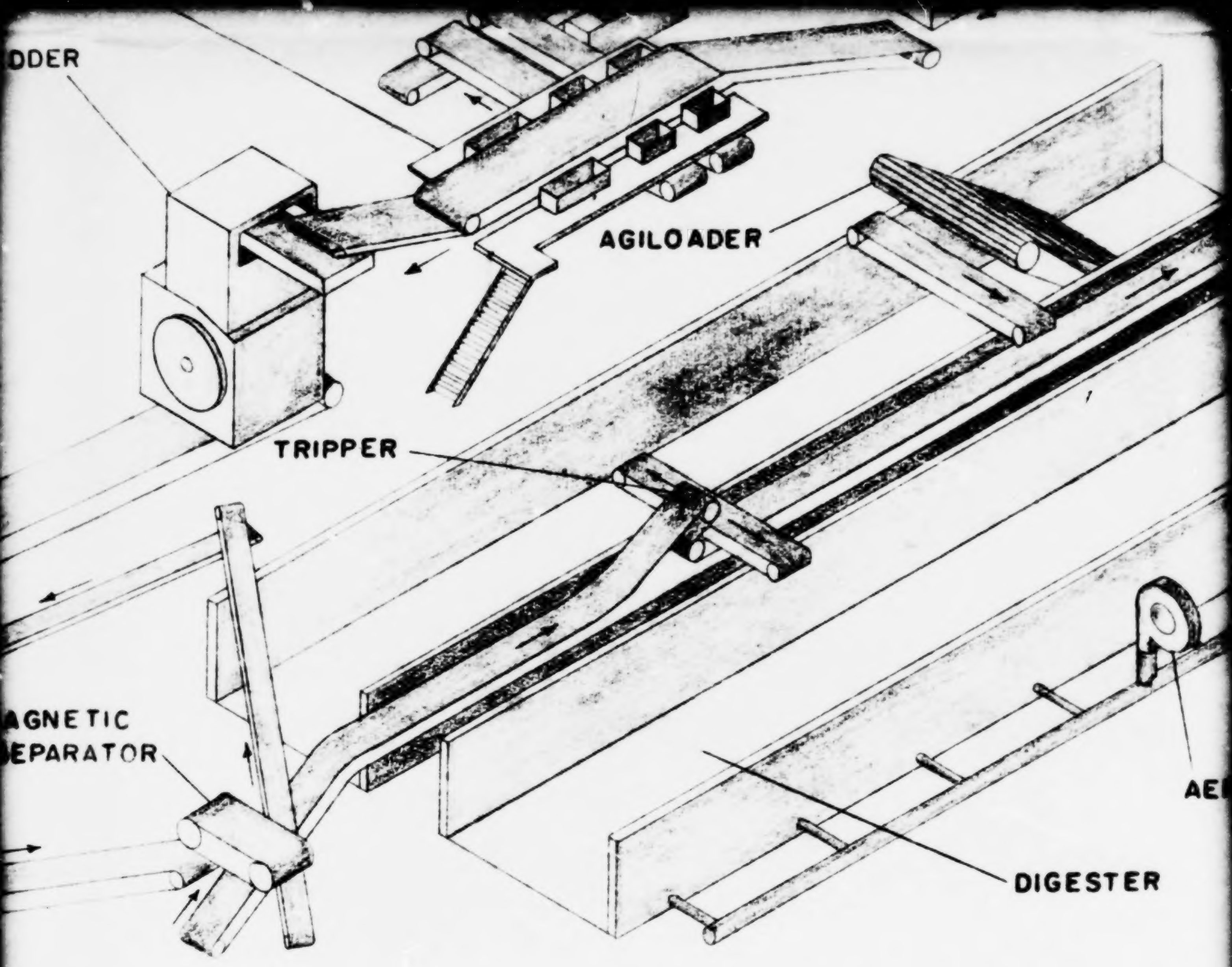
WILLIAMS
SECONDARY
SHREDDER
MAGNETIC
SEPARATO
MIXING SCREWS
B
A


DDER
AGILOADER
TRIPPER
AGNETIC
EPARATOR
AE
DIGESTER

3 1 2

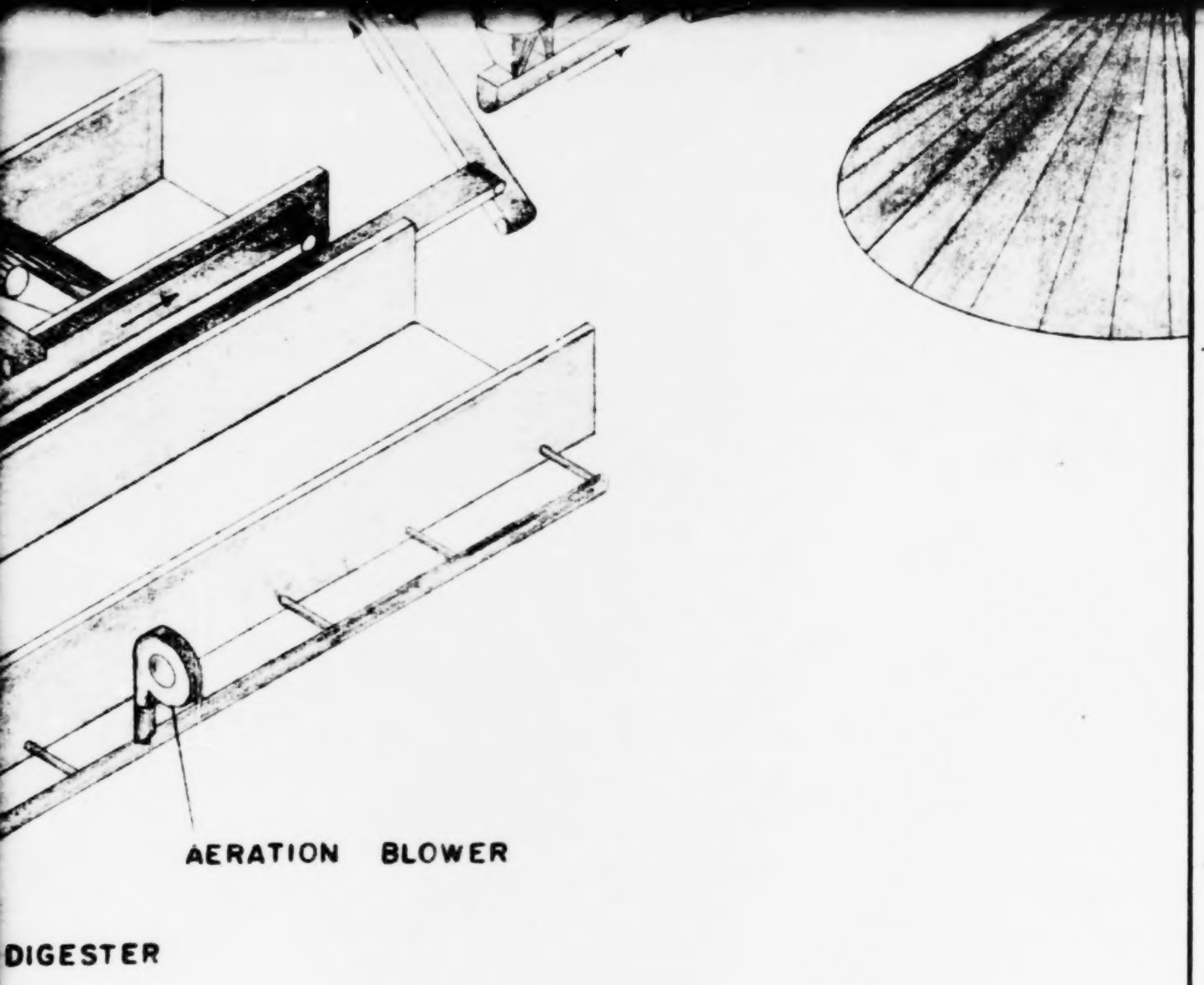

AERATION BLOWER
DIGESTER
C
B
A
1
1

FIG. 6

FLOW DIAGRAM FOR
RUBBISH PLANT

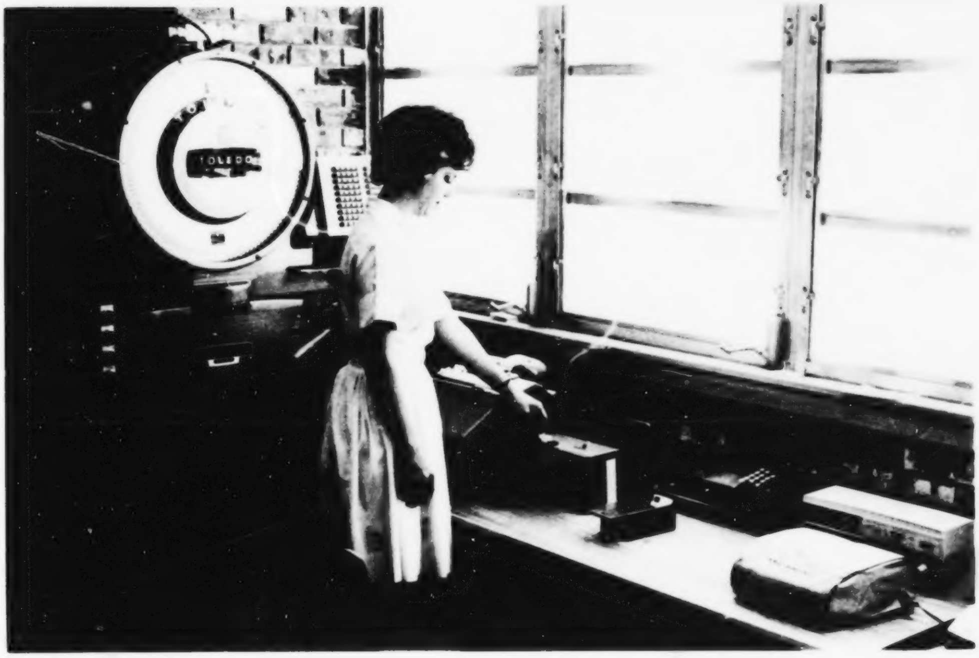


FIGURE 7

Truck Scale

2. Receiving Hopper and Apron Conveyor (Figures 8 and 9)

Refuse is dumped into the receiving hopper which is 66' long, 12' wide and 12' - 6" deep. The capacity of the hopper is about 60 tons of refuse. An apron conveyor located at the bottom of this hopper carries refuse into the oscillating conveyor. The apron conveyor consists of a series of overlapping or interlocking apron pans which make up the bottom of the receiving hopper. These same are attached successively to three steel chains which are driven by a 2 HP S. Electrical Motors Varidrive, giving a variable conveyor speed of approximately 2 feet to 20 feet per minute. The apron conveyor is controlled from the control console. The conveyor, Model No. 74-6, was manufactured by Gulf Machinery Company, Safety Harbor, Florida, using Link-Belt Company components. The apron conveyor is designed to move the entire receiving hopper load. Speed of the apron conveyor can be controlled to drop up to about 20 tons per hour into the oscillating conveyor.

3. Control Console (Figure 10)

A control center is stationed on a high platform to regulate the flow of refuse material through the plant. This control platform is so located that the operator can oversee the entire system. The platform is 13' - 10" above the plant floor and is approximately 14' x 15' square. The platform was manufactured on the site from drawings supplied by Metropolitan.

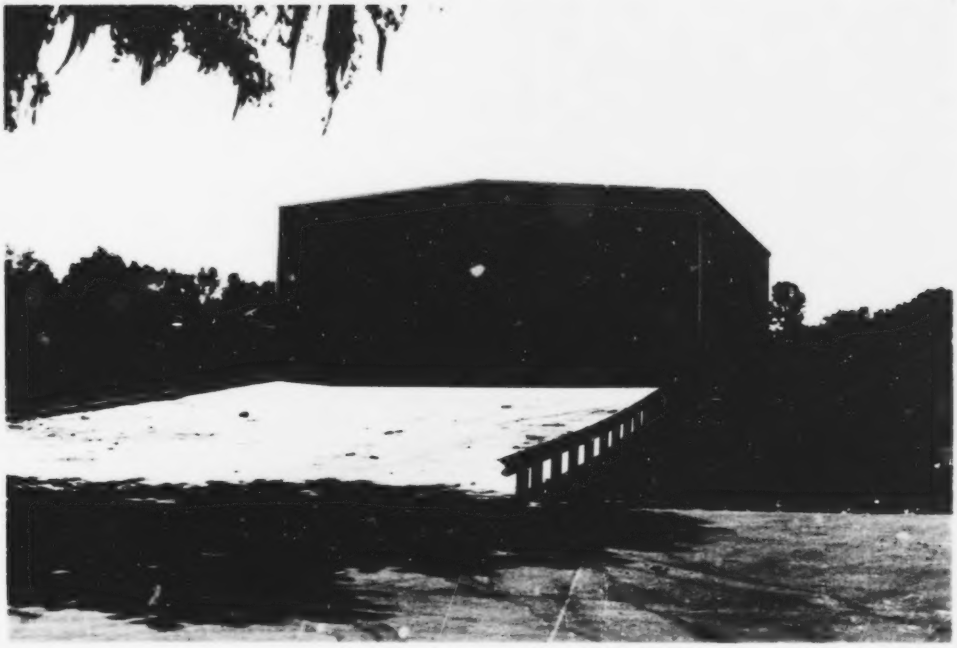


FIGURE 8

Receiving Hopper and Apron Conveyor

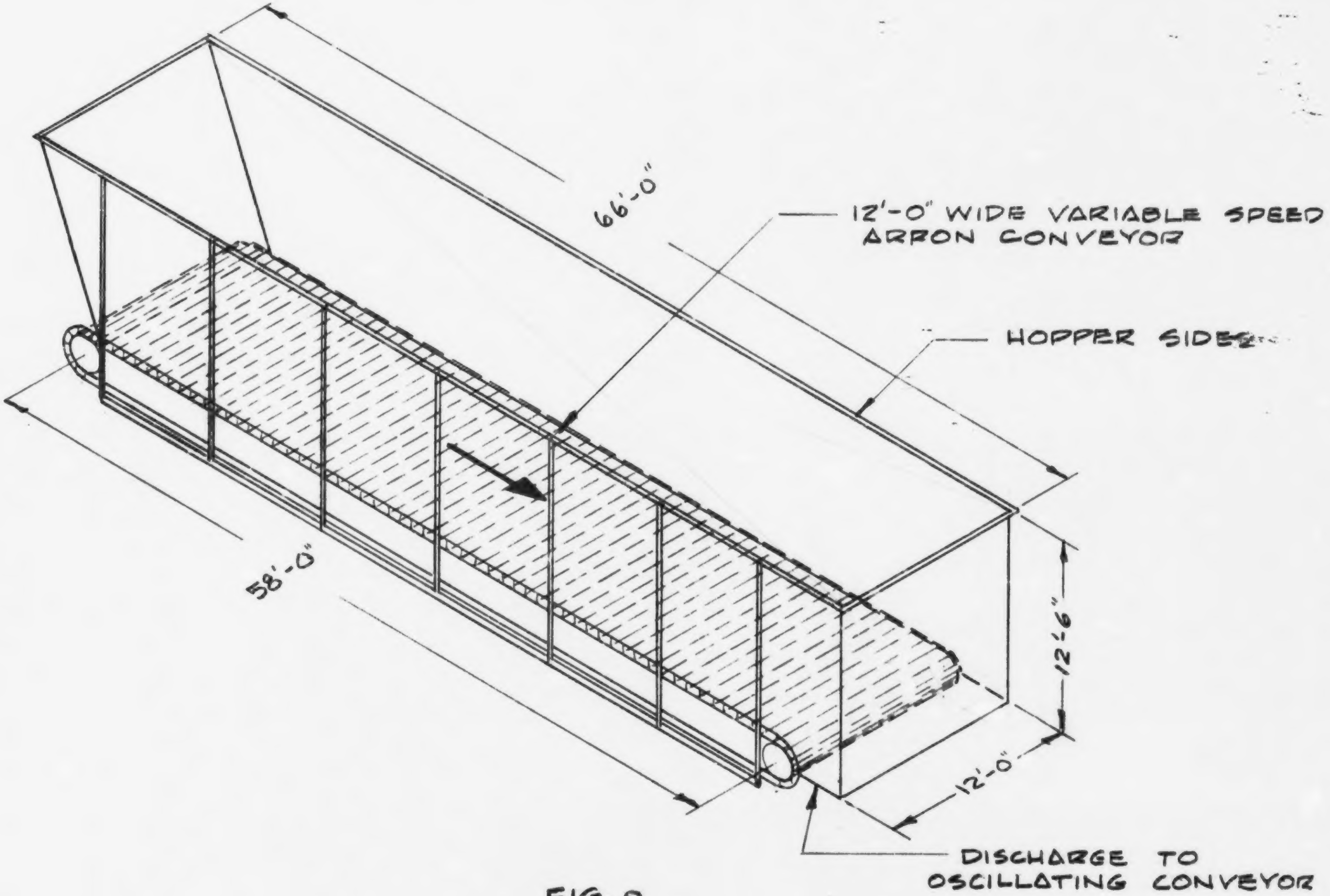

66'-0"
12'-0" WIDE VARIABLE SPEED
APRON CONVEYOR
HOPPER SIDES
58'-0"
12'-6"
12'-0"
DISCHARGE TO
OSCILLATING CONVEYOR

FIG. 9
RECEIVING HOPPER WITH
APRON CONVEYOR

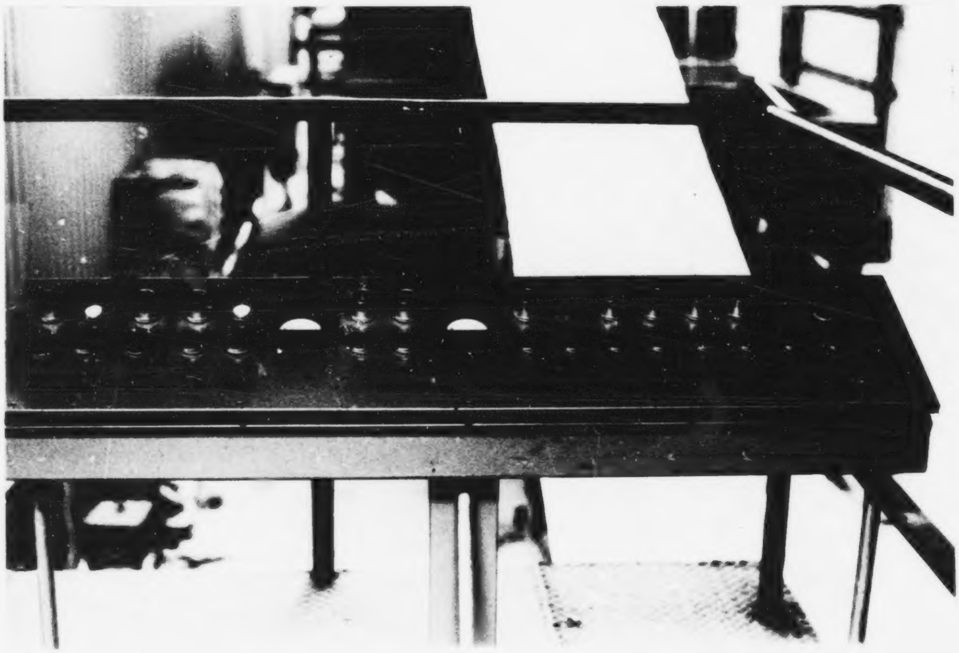


FIGURE 10

Control Console

The Control Console consists of a 30' high column on which a control panel is fastened. This panel contains start-and-stop switches for the following equipment: Apron Conveyor, Oscillating Conveyor, Sorting Belt, Primary Grinder, Ballistic Separator, Secondary Grinder, Intermediate Conveyor, two Screw Conveyors, Moyno Pump, Transfer Conveyor and Tripper Conveyor. The Sorting Belt and Apron Conveyors are also equipped with a fast-and-slow speed switch. All switches are plainly marked, using red lights to indicate when the machinery is in operation. The manufacturer was McCleery Engineering and Manufacturing Company, Inc., Downers Grove, Illinois.

4. Oscillating Conveyor

The Oscillating Conveyor receives refuse from the Apron Conveyor and feeds it to the Sorting Belt Conveyor. An oscillating conveyor serves to break or loosen packed refuse, and to move the refuse in a smooth, continuous, uniform flow. In effect, it "meters" the amount fed to the sorting conveyor at a material flow rate of up to 20 tons per hour. This is accomplished by the upward and forward oscillating motion of a metal trough mounted on inclined reactor legs. A constant stroke eccentric drive provides a powerful surge-proof conveying action. The stroke is about 7/8" and the cycle rate is about 200 per minute. The Oscillating Conveyor is 20' long x 5' wide and 18" deep, and is powered by a

10 h.p. motor. It is controlled from the Control Console to insure that the proper amount of refuse is fed onto the Sorting Belt. This conveyor is a coil-mounted type, manufactured by Link-Belt Company, Chicago.

5. Sorting Conveyor

The refuse is fed by the Oscillating Conveyor onto the Sorting Conveyor at a rate of up to 20 tons per hour. The Sorting Conveyor is a belt conveyor 83 feet long and 5 feet wide, which rises from below the floor level to the sorting platform, at a height of 15 feet. It is powered by a 5 h.p. U. S. Electrical Motors Co. varidrive giving a variable conveyor speed ranging from approximately 10 feet per minute to 30 feet per minute. This unit is also controlled from the Control Console. The Sorting Belt, Model No. 74-23, was manufactured by Gulf Machinery Company, Safety Harbor, Florida, using Link-Belt Company components, and was assembled at the Gainesville site.

6. Sorting Platform (Figure 11)

The refuse is elevated to the Sorting Platform where normally six sorters stand on the platform, three on each side of the sorting belt. Drop-out chutes are built into the platforms. As the refuse passes by on the conveyor belt the sorters manually remove salvage grade waste paper and cardboard, which are dropped down the chutes. Textiles and non-ferrous metals can also be removed manually. Normally, salvageable paper items will total about 4% to 8% of the input total, and textiles and non-ferrous items from 1/2% to 1%.

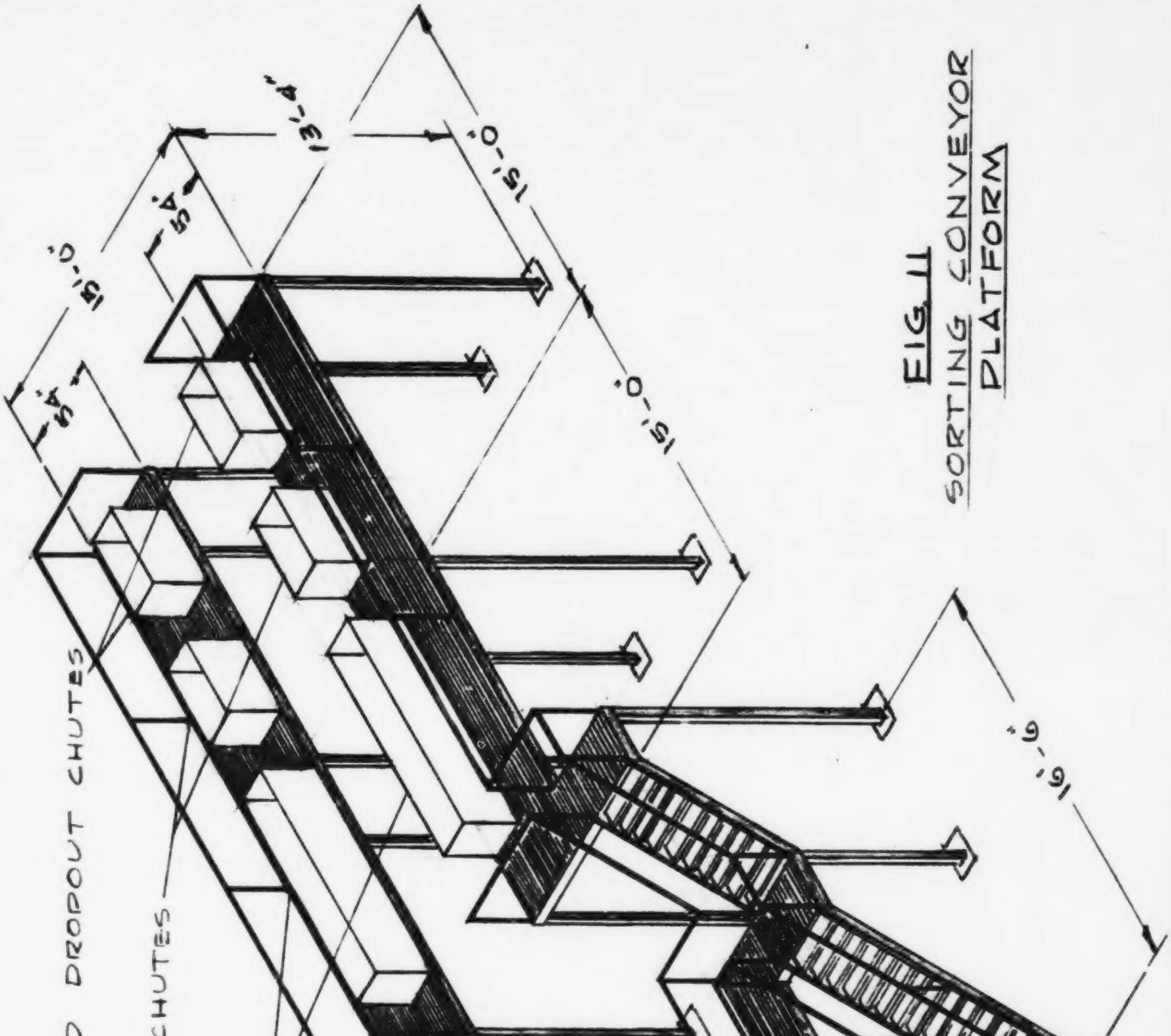

CARDBOARD DROPOUT CHUTES
NEWSPRINT DROPOUT CHUTES
NON-COMPOSTABLE DROPOUT CHUTES
8'-4"
15'-0"
5'-4"
13'-4"
15'-0"
15'-0"
16'-6"
8'-3¼"
23'-4"

FIG 11
SORTING CONVEYOR PLATFORM

Paper and cardboard are dropped into separate collector-conveyor systems which hold about one bale each, and feed automatically into the baler. Textiles and non-ferrous metals are sorted into separate containers. At the last station, materials which are non-salvageable and non-compostable (including such items as rubber hose, tires, broken furniture, mattresses, rugs, large plastic items, large bulky items, large tree branches, stumps, etc.) are also manually removed and dropped through chutes into a dump truck, to be taken to a landfill. These materials may comprise 10% to 14% of the incoming refuse. The platform was manufactured by Gulf Machinery Company, Safety Harbor, Florida, from drawings by Metropolitan, and was assembled at the plant site.

D. PAPER SALVAGE SYSTEM

1. Collector Conveyor System

The sorting platform is divided by the sorting belt into two separate sides. Each side has three dropout chutes. These are arranged in pairs on opposite sides of the platform, the first pair feeding the first collector-conveyor, the second pair feeding the second collector-conveyor, and the third pair feeds the non-compostables directly into a truck. Normally, one collector-conveyor will be used for newsprint and other white papers, and the other for cardboard, corrugated and other kraft type papers.

The collector-conveyors run underneath the sorting platform at right angles to the sorting belt. These conveyors are about 4 feet below the chutes, creating storage for about 1 1/2 bales of newsprint or about 1 bale of cardboard. A common belt conveyor (Baler Conveyor) connects the 2 cross-conveyors with the baler. By allowing one collector-conveyor to stand idle while the other is feeding the baler, only one baler is needed to bale the two different types of salvage paper. The two collector-conveyors and the baler conveyor were all manufactured by Gulf Machinery Company, Safety Harbor, Florida. The cardboard collector is Model No. 74-47, the newspaper collector is Model No. 74-42. Both conveyors are 48 inches wide by 16 feet long. The Baler Conveyor is 36 inches wide by 15 feet long, and is Model No. 74-43. All three conveyors are driven by 1 HP electric motors and have a belt speed of about 80 feet per minute.

2. Baler (Figure 12)

The baler for the plant was manufactured by the Maren Engineering Corporation of South Holland, Illinois. Its baling chamber is 60" long by 30" wide by 42" high. The operating pressure of 1500 P.S.I. can compress a bale of mixed paper up to 1,000 lbs per bale. The total length of the baler is 18 feet long and its weight is approximately 7,000 lbs.

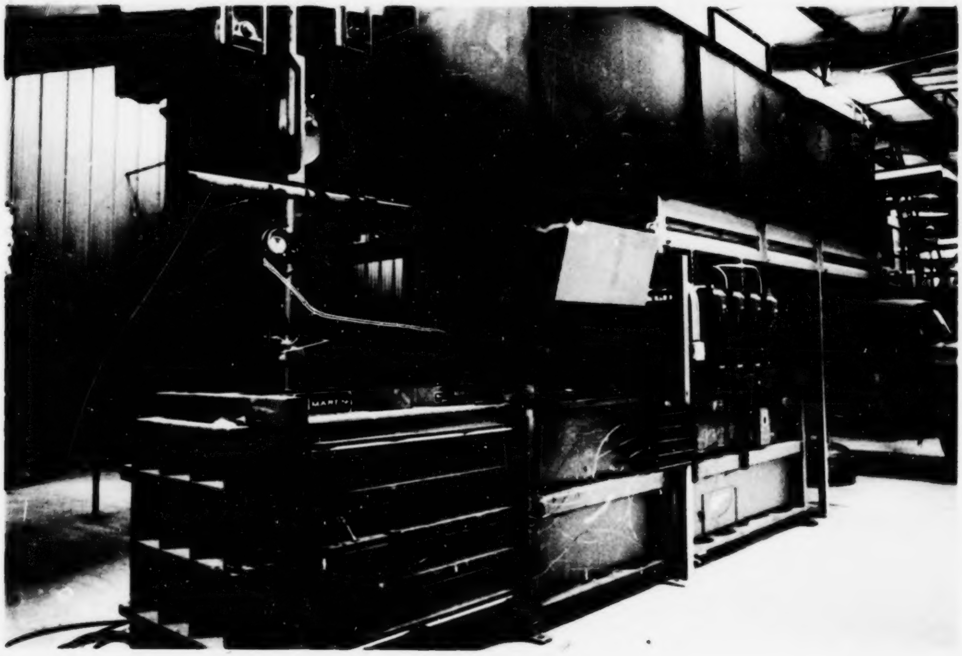


FIGURE 12

Baler

E. GRINDING SYSTEM

The original plant design included a Model CDM-4824-HD Crusher Disintegrator made by Centriblast Corporation, a subsidiary of Joy Manufacturing Company, along with a Ballistic Separator. This combination did not work in a satisfactory manner; a change was made in June of 1969. The change consisted of replacing the above mentioned items with a new Williams Hammermill, fed by an additional Oscillating Conveyor, in combination with an electromagnet.

1. Crusher-Disintegrator (Figure 13)

Prior to the replacement of the Centriblast machine with the Williams Hammermill, refuse was handled in the following manner: After the refuse has passed the sorting area and most of the salvageable cardboard, paper and other materials have been manually removed, the remaining refuse is fed directly into a crusher-disintegrator.

In the operation of the machine, refuse is force-fed into the crushing section by "live" top and bottom sections of the feed hopper. This system consists of converging upper and lower apron conveyors, each driven by a 7 1/2 HP gear-motor. The upper gear-motor also drives a set of slow-revolving star wheels. The feed end is large enough to receive fairly bulky items. The largest article handled to date without causing a jam or a major breakdown was a heavy cardboard box about 30 inches high by 36 inches wide. Incoming refuse is forced toward the disintegrator section, and is crushed into a flattened mass about 4 inches thick which passes through the small discharge opening.

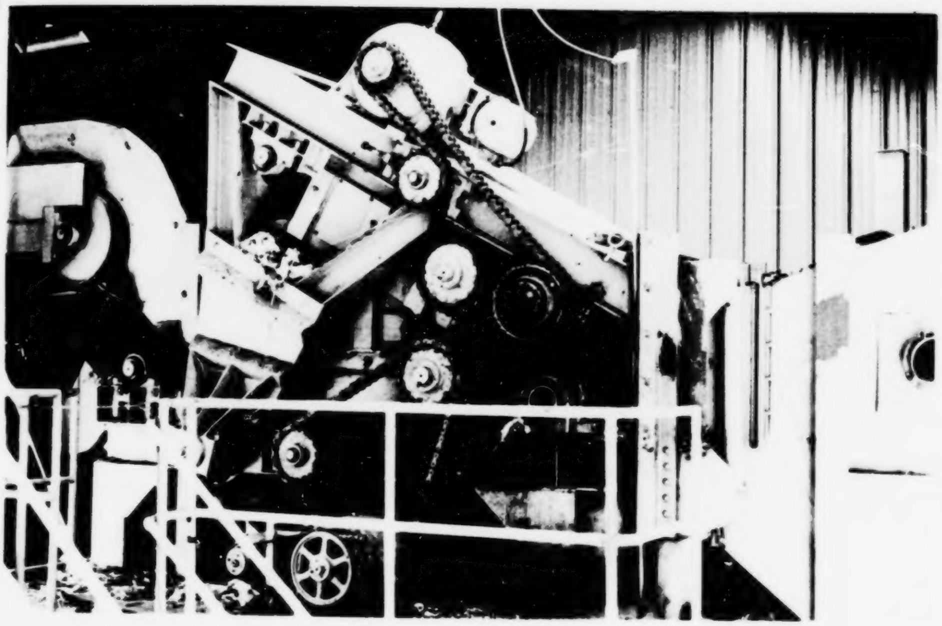


FIGURE 13

Crusher-Disintegrator

At the discharge end the refuse mass is gripped by a slowly revolving "star" shaft with equally spaced star-shaped rings or wheels. Parallel to this shaft is a high speed "disintegrator" shaft with heavy-duty impactors spaced to rotate between the star rings on the star shaft. This shaft is driven by a 300 h.p. electric motor, and rotates at up to 1,000 RPM. The shafts are so arranged that the impactors and star wheels comb through each other. Both star wheels and impactors make point penetration of the refuse. The star acts as an anvil for a secondary tearing action. In addition, the close clearance between the impactors and the star wheel shaft provides a third disintegration effect, a shearing action.

The particle size varies with the type of material being fed into the machine, but for general refuse the average size discharged is about 3 inches by 3 inches.

2. Ballistic Separator (Figure 14)

The refuse at this point has passed through the Grinder-Disintegrator and is discharged at high velocity into the Ballistic Separator. The principal of the Ballistic Separator is separation by momentum of individual materials. The more dense particles (mostly metal) will be thrown farther than the lighter particles (such as paper and compostable material). The metals and other heavier materials are ballistically separated on to an upper discharge belt conveyor which conveys the material to the can conveyor.

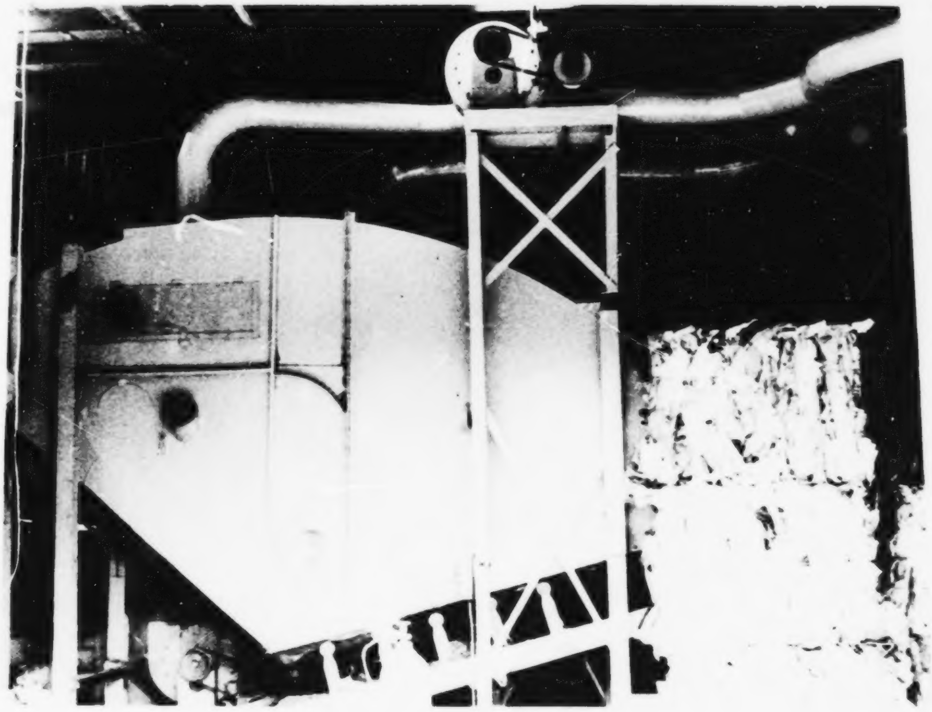


FIGURE 14

Ballistic Separator

The lighter materials that fall nearer the Grinder-Disintegrator are caught in a hopper which discharges into a slinger. This slinger is a high speed belt which accelerates the heavier materials and gives this heavier material velocity to provide a second step for ballistic separation, again separating any heavier materials which are conveyed to the can conveyor. The speed and angle of slope of the belt was adjusted on the "cut and try" method to attain optimum separation. All materials that are not thrown onto the upper discharge belt conveyor by ballistic force fall on to the lower discharge belt conveyor and are conveyed to the secondary grinder.

Located at strategic points in the sides of the ballistic separator are two air inlets and two suction ports where two blowers using variable speed drives supply air to the inlets and two blowers (also variable speed) supply suction for the suction ports. Paper, plastics and other very light materials are removed with this air system and blown into a burner, giving efficient disposal and providing a useful source of heat for processing.

The ballistic separator is made of 1/4 inch mild steel plate with abrasive resistant wear plates bolted to the inside wearing surfaces. There are two upper access doors near the top of the separator which are used for ease of maintenance on the Grinder-Disintegrator. One large walk-through door is located lower on the separator just above the lower discharge belt which was used for cleaning purposes; also, six glass shop portholes are used in the sides of the separator for viewing the operation of the separator. This unit was manufactured by Dan B. Vincent, Inc., Tampa, Florida. The upper discharge belt was manufactured by Gulf Machinery Company, Safety Harbor, Florida, their model No. 74-25. It is driven by a 1 h.p. electric motor (1800 RPM), is 30 inches wide by 23 feet long, and conveys approximately 0.4 tons per hour of metal from the ballistic separator to the can conveyor at about 106 feet per minute.

The slinger is a 30 inch wide high-speed belt traveling at from 1500 to 3500 feet per minute, and is driven by a 7 1/2 h.p. motor on a sliding variable-speed motor base having a three-to-one ratio variable-type motor belt pulley. It was manufactured by Stephens-Adamson Corporation, Aurora, Illinois, and modified by Dan B. Vincent, Inc., Tampa, Florida, to fit the ballistic separator.

Items 1 and 2 described above were removed because of unsatisfactory service and new equipment installed in its place. This equipment is described in Items 3 through 5 as follows.

3. Oscillating Conveyor

In the new revised design the primary grinder was offset to the right of the picking belt with a Link-Belt Type C extra heavy duty coilmount Oscillating Conveyor receiving the sorted refuse from the picking belt and feeding the material in a more uniform flow into the new primary grinder. This conveyor is 12' long, 62" wide and 18" deep. The unit was complete with a 14,000 pound double-arm, positive action 1" stroke drive assembly and run with a 10 HP 1200 RPM motor.

Because of the blow back of material onto the conveyor from the velocity of the hammers in the primary grinder, the sides of the oscillator were raised an additional four feet above the 18" depth. A hood was also installed over the conveyor in order to help control dirt and dust.

4. Primary Grinder

The new grinder is a Williams Model #460, Type K Shredder, manufactured by the Williams Patent Crusher Company, St. Louis, Missouri. This machine is very similar to the Williams secondary mill in use since the plant was constructed. It was selected over other mills because of its past superior performance in grinding heterogeneous materials. This mill is 91 1/2" long, 143" wide and 57" high, with a 60" x 54" feed opening. It weighs approximately 33,500 lbs. Accessibility into the mill to change hammers is facilitated by a hydraulic system for opening the cover assembly. This grinder has 30-100 lb hammers mounted on four banks around the shaft. The mill is also equipped with double cage-bar grates with space openings varying from 4 1/2" x 8" to 12" x 8". The larger size openings will allow large pieces of metal to escape. The refuse is reduced to about 4" to 6" particle size in preparation for entering the secondary mill. The shredder is run by direct drive with a 400 HP U.S. Electric Motor which runs at about 900 RPM. The rated capacity of this mill is 35 tons per hour. The starting equipment for this motor is manufactured by Square D Company and is similar to the equipment used for starting the secondary grinder motor.

5. Electromagnet

This unit replaced the Ballistic Separator as a means of separating ferrous metal from the waste stream. It is a Model SE-555 Eriez Electromagnet including a rectifier. The magnet is a center pole type, weighing approximately 8500 lbs. Overall dimensions are 70" x 115" x 38".

6. Secondary Grinder

Since the primary grinder was offset from the original production line, the Intermediate Belt was also offset. So beyond the new magnet an additional conveyor was installed to feed directly into the secondary grinder.

The purpose of the secondary grinder is to further reduce particle size which in turn increases material density, and so increases digester capacity. This is accomplished with a hammer mill type grinder manufactured by Williams Patent Crusher Company of St. Louis, Missouri. The model used is a GA-70, with a rated capacity of 20 tons per hour. Overall size is 68" wide, 132" long, and 58" high, weighing 19,500 lbs. This is also run with a direct drive, 400 HP, 1200 RPM U.S. Electric Motor. The unit reduces the material by impact from a set of 30-50 lb. hammers striking the material against breaker plates until it is fine enough to pass through the openings of the grates located in the lower section of the grinder. Grate openings can be varied to control particle size. The openings in this grinder are 10 1/2" x 3", which reduces particle size to 1" to 2" pieces.

F. SLUDGE HANDLING SYSTEM

1. Mixing Screws (Figure 15)

After the refuse has been discharged from the bottom of the secondary grinder, it falls into the mixing screws where two counter-rotating ribbon-type screws, placed side by side in a common trough, blend the material with the sludge as it is moved down the trough. At this point in the process, the material is otherwise too dry for composting and it has been found advantageous to introduce moisture (which can be either water or sewage sludge). The twin screws mix together the liquid and dry refuse. The moisture content of the material entering the digesters should be 50 to 65 percent. Since mixed refuse normally ranges from 20 to 25 percent moisture, additional liquid must be added to the shredded refuse prior to composting. Sludge from the adjacent City Sewage Treatment Plant is normally used as the moistening agent.

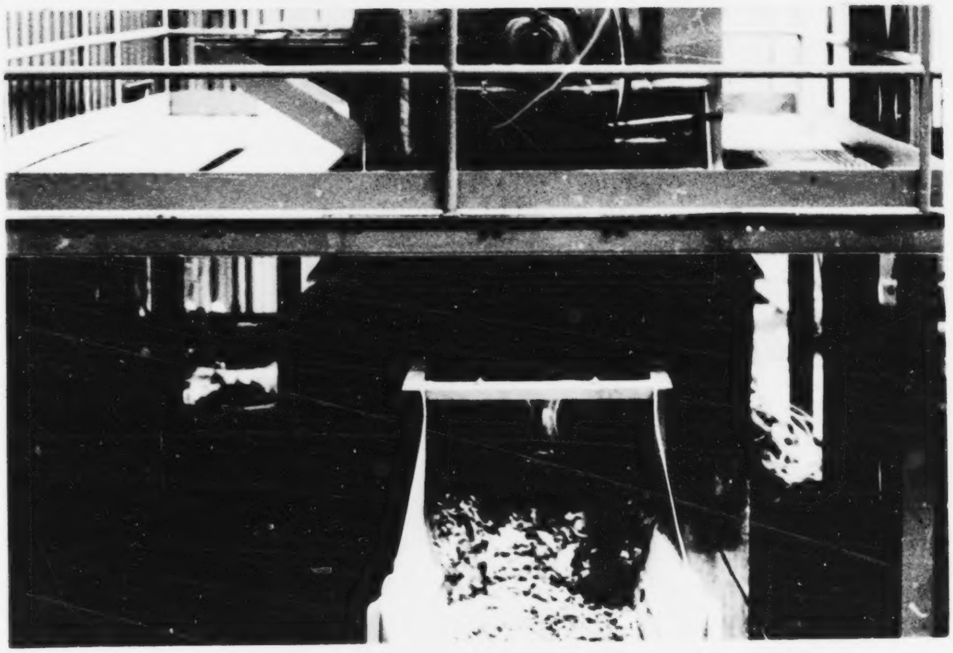


FIGURE 15

Mixing Screws

The mixing screw and trough were manufactured by Gulf Machinery Company, Safety Harbor, Florida, Model No. 74-29. The screws are 16 inches in diameter, and the trough measures 34 inches wide by 12 feet long. Each screw is driven by a 3 HP Electric Motor giving a speed of 45 RPM.

2. Sludge Tank (Figures 16, 17, and 18)

Sludge from the City Sewage Treatment Plant, adjacent to the compost plant, is pumped by the City into a concrete sludge storage tank, located near the grinding and sorting building of the compost plant. The Sludge Tank is 18 feet by 18 feet square by 16 feet deep, with walls 1 foot thick. It has a sloping bottom to a center trough, at one end of which is the outlet pipe for the sludge pump. Use of the sludge storage tank permits the compost plant to use sludge at a uniform rate, and at the same time it gives flexibility for maximum surge supply when the plant is operating at full capacity or none when no refuse is processed. The City Sewage Treatment Plant is able to furnish digested sludge at about 1.5 percent solids content, raw sludge at about the same solids content, or raw sludge thickened to almost 6 percent solids.

3. Sludge Pump

A "Moyno" brand "Progressing cavity" pump is used to convey sludge from the tank to the mixing screws. The pump is manufactured by Robbins Myers, Inc., pump division, Springfield, Ohio, Model No. SWG8. The pump is driven by a 3 HP U.S. Electric Motors "Varidrive" unit with a 4 to 1 variable ratio. This gives

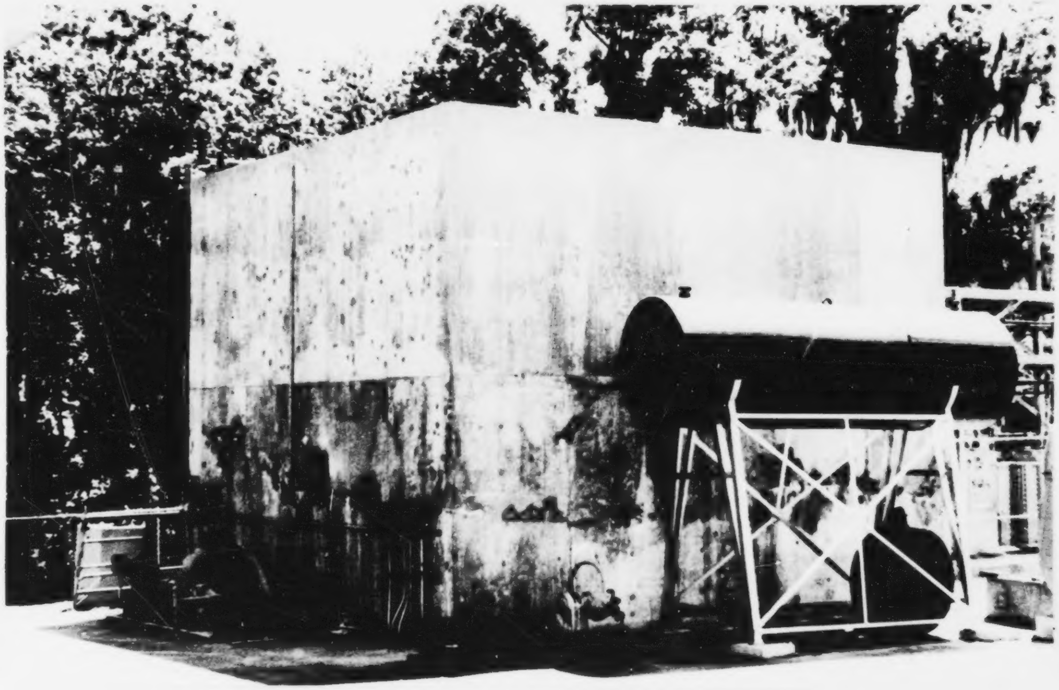


FIGURE 16

Sludge Tank

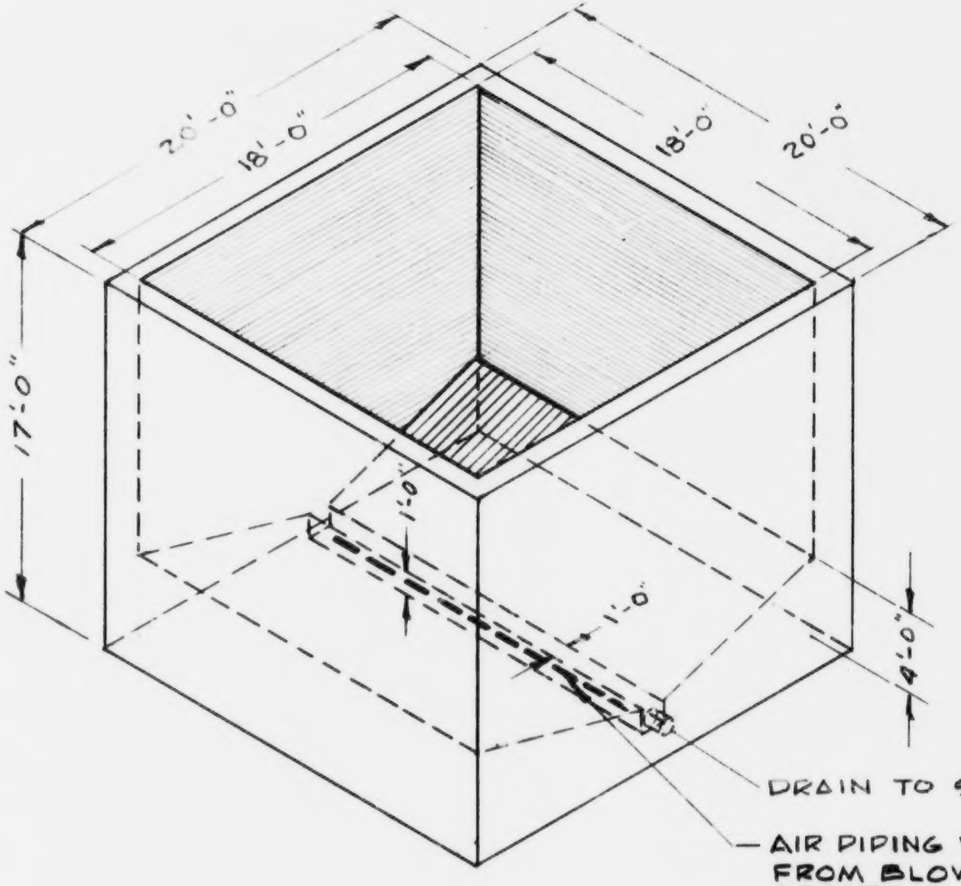

20'-0"
18'-0"
18'-0"
20'-0"
17'-0"
1'-0"
1'-0"
4'-0"
DRAIN TO SLUDGE PUMP
AIR PIPING W/OUTLET NOZZLES FROM BLOWER FOR SLUDGE AERATION.

FIG. 17

SLUDGE STORAGE TANK

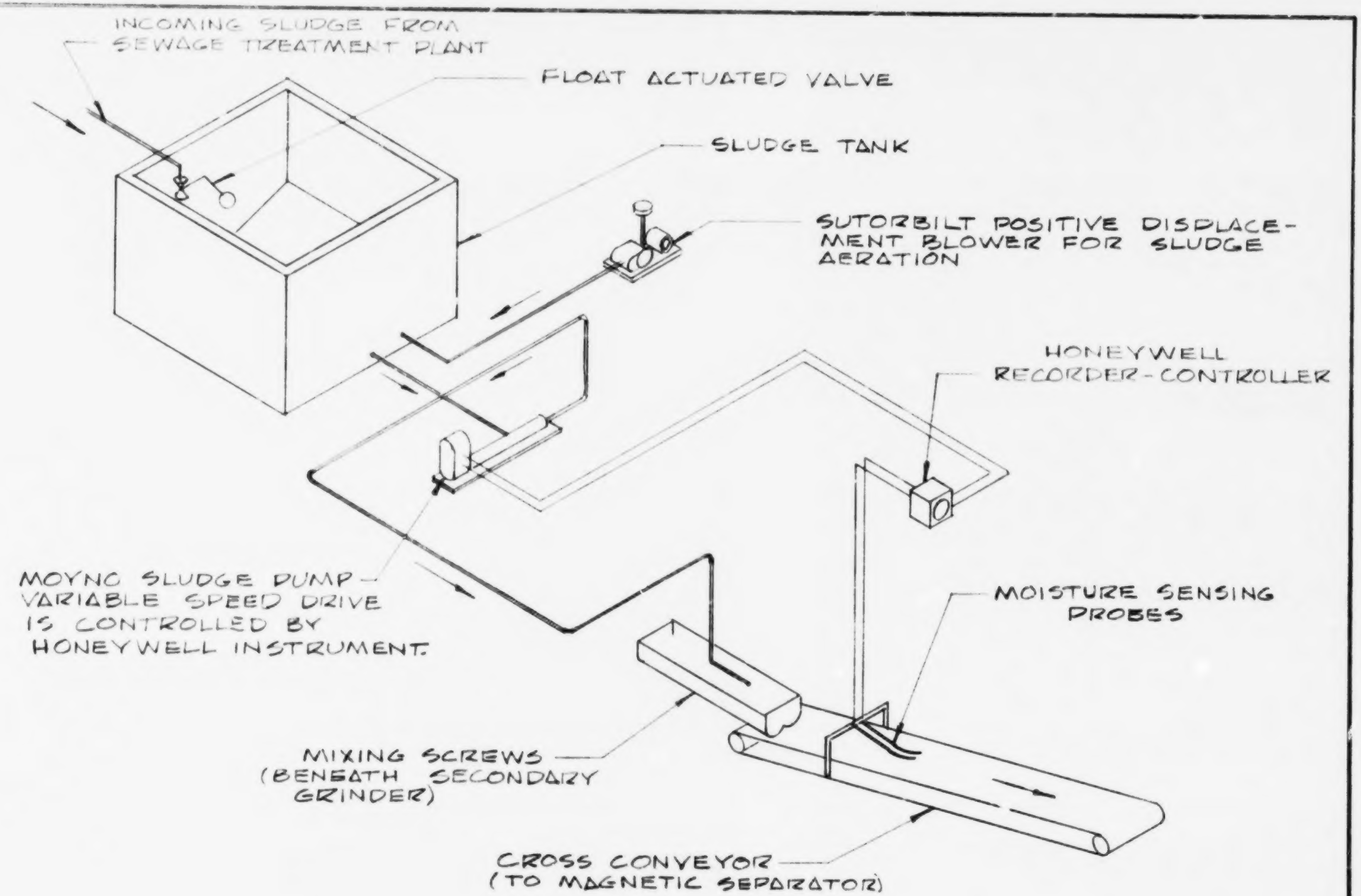

INCOMING SLUDGE FROM SEWAGE TREATMENT PLANT
FLOAT ACTUATED VALVE
SLUDGE TANK
SUTORBILT POSITIVE DISPLACEMENT BLOWER FOR SLUDGE AERATION
HONEYWELL RECORDER-CONTROLLER
MOYNO SLUDGE PUMP - VARIABLE SPEED DRIVE IS CONTROLLED BY HONEYWELL INSTRUMENT.
MOISTURE SENSING PROBES
MIXING SCREWS (BENEATH SECONDARY GRINDER)
CROSS CONVEYOR (TO MAGNETIC SEPARATOR)

FIG. 18

SLUDGE HANDLING SYSTEM

an output ranging from 10 gallons per minute at 105 RPM to 50 gallons per minute at 420 RPM. The original design called for the varidrive unit being controlled by a Honeywell Automatic Moisture Sensing device.

4. Automatic Moisture Sensor

The moisture sensing device uses electrical conductivity between two electronic sensing electrodes. These are two metal shoes, 1 1/4 inches wide x 4 1/4 inches on center, which are mounted on a pivoted arm riding on the surface of the ground refuse. The electrodes comprise one leg of an A.C. bridge circuit. This signal is used to control the variable-speed drive on the Moyno Pump which meters sludge from the tank to the mixing screws beneath the secondary grinder. The pump can also be manually controlled, on or off, from the Control Console. The input signal from the probes passes through a recorder which maintains a continuous record of the moisture content of the raw refuse. The entire moisture control system failed to work properly and it was abandoned in favor of manual control.

5. Aeration System

The city sewage sludge in the Sludge Storage Tank is aerated by a positive pressure blower located at the side of the sludge tank. This air is supplied through nozzles in a pipe manifold at the bottom of the tank. This positive pressure blower is manufactured by Sutorbilt Corporation, Compton, California, Model No. 3H. It is rated at 42 CFM at 2.5 PSI, operates at 1670 RPM, and is powered by a 3 HP electric motor.

6. Transfer Belt

After having been mixed with sludge, the ground refuse drops onto a 30" x 26' long conveyor, which conveys it under an electromagnetic separator and onto a tripper belt where it is emptied into the digestion tank. The conveyor was manufactured by Gulf Machinery Company, Safety Harbor, Florida. It is driven by a 2 HP motor which moves the belt at a speed of about 250 feet per minute.

G. DIGESTER SYSTEM

1. Electromagnet (Figure 19)

An electromagnet is located at the south end of the digestion tanks just over the end of the Tripper Belt. This magnet removes most of the ferrous metals from the ground refuse prior to its being deposited in the digestion tanks. The magnet is an Eriez SE-1300 run with a 3 HP motor. It has a 30" wide belt.

2. Tripper Belt Conveyor (Figure 20)

After the refuse passes under the magnetic separator and the ferrous metal has been removed, it is then carried by the Tripper Belt Conveyor to the Tripper which unloads the ground

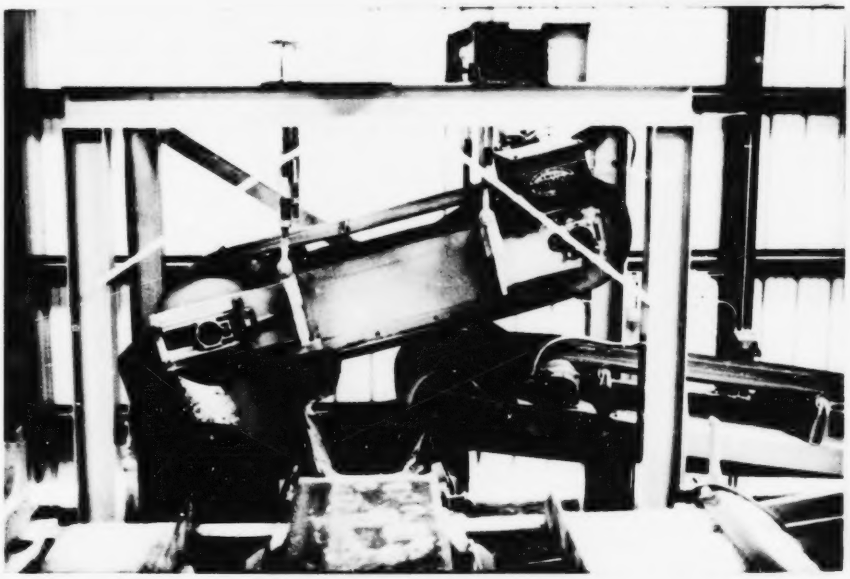


FIGURE 19

Electromagnet

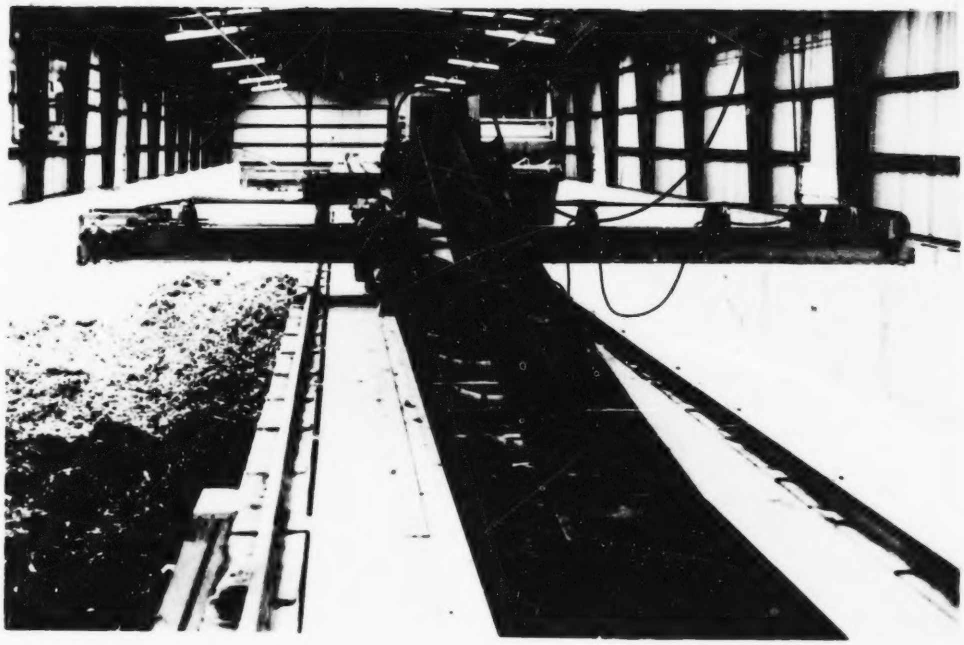


FIGURE 20

Tripper Belt Conveyor

and moistened refuse into the digester tanks (Metro-Waste Patent No. 3,323,896). The tripper belt is 360 feet long by 22 inches wide. It moves approximately 450 feet per minute, and is driven by a 7 1/2 HP gearmotor. The tripper belt travels the full usable length of the digester tanks.

3. Tripper with Shuttle Conveyor (Early Version) (Figure 21)

This companion to the Tripper is positioned at 90° to the tripper belt conveyor and is designed to discharge the refuse evenly into the digesters by moving the discharge end to any position over either digester. This is done by manually winching the shuttle back and forth as required, using a cable-operated winch system. The refuse is conveyed on the tripper belt, which carries it to the tripper, which discharges it onto the shuttle conveyor belt. This transfer is accomplished by means of a movable tripper device which elevates the loaded belt and then passes it successively over two large reversing idlers. The material is then carried by the shuttle conveyor to desired area in the digester tanks. The shuttle conveyor was manufactured by Gulf Machinery Company, Safety Harbor, Florida, Model No. 74-40. It is powered by a 1 HP electric motor. The belt speed is approximately 475 feet per minute. Due to the length of the Tripper Belt Conveyor, it is at times possible to load and unload the Digester Tanks at the same time.

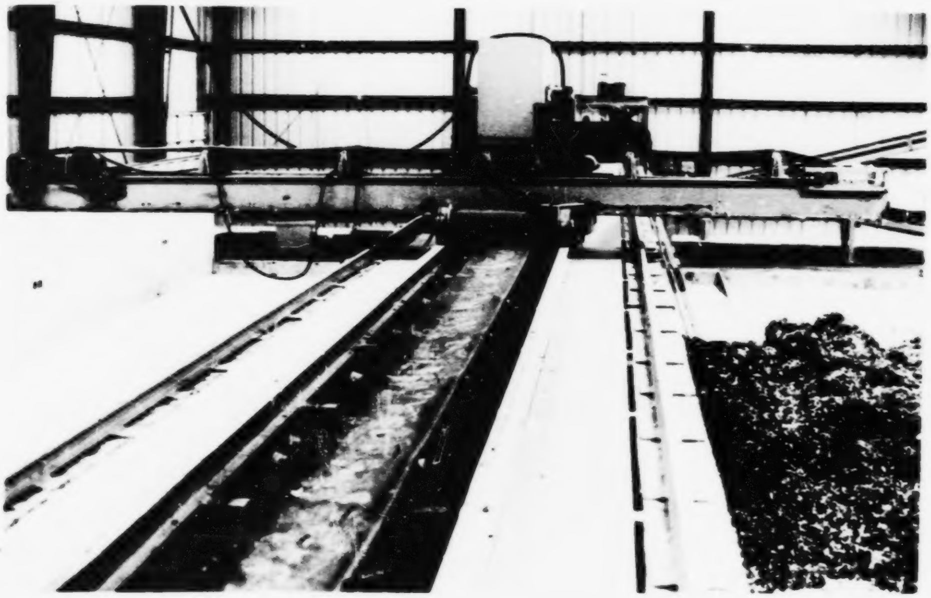


FIGURE 21

Tripper with Shuttle Conveyor

4. Tripper with Shuttle Conveyor (Late Version)

Problems were encountered with the shuttle on the original tripper. As mentioned, this shuttle was positioned 90° to the tripper belt and when it was extended to its full length, the weight of the shuttle was so great it tended to tip the tripper off the track. The shuttle was replaced with one of lighter weight materials. It was mounted so as to swivel a full 180°.

5. Digester Tanks (Figure 22)

There are two digester tanks 330' long by 20' wide by 9' deep in which the ground refuse is composted. The walls are constructed of concrete blocks. The floor consists of perforated plates made from 20 gal galvanized steel. The face of the plate is 7 inches wide with a 1 3/8 inch deep channel lock to hold each plate in position. Each panel has rows of staggered air slots 1 1/4 inch long on 1 3/4 inch centers, (rows are 3/4" apart) and the slots are extruded to a height of 1/8 inch to 3/16 inch, the extrusion being at an angle to partially shield the slot from foreign material. These extrusions provide a total opening in the plate of about 14%. This perforated floor is also rated to support a possible loading of 6,000 pounds per square foot.

River gravel about 1/4" diameter covers the perforated plates to a depth of 3" to 4" over the entire floor surface of the tank. The perforated floor and rock help to diffuse air

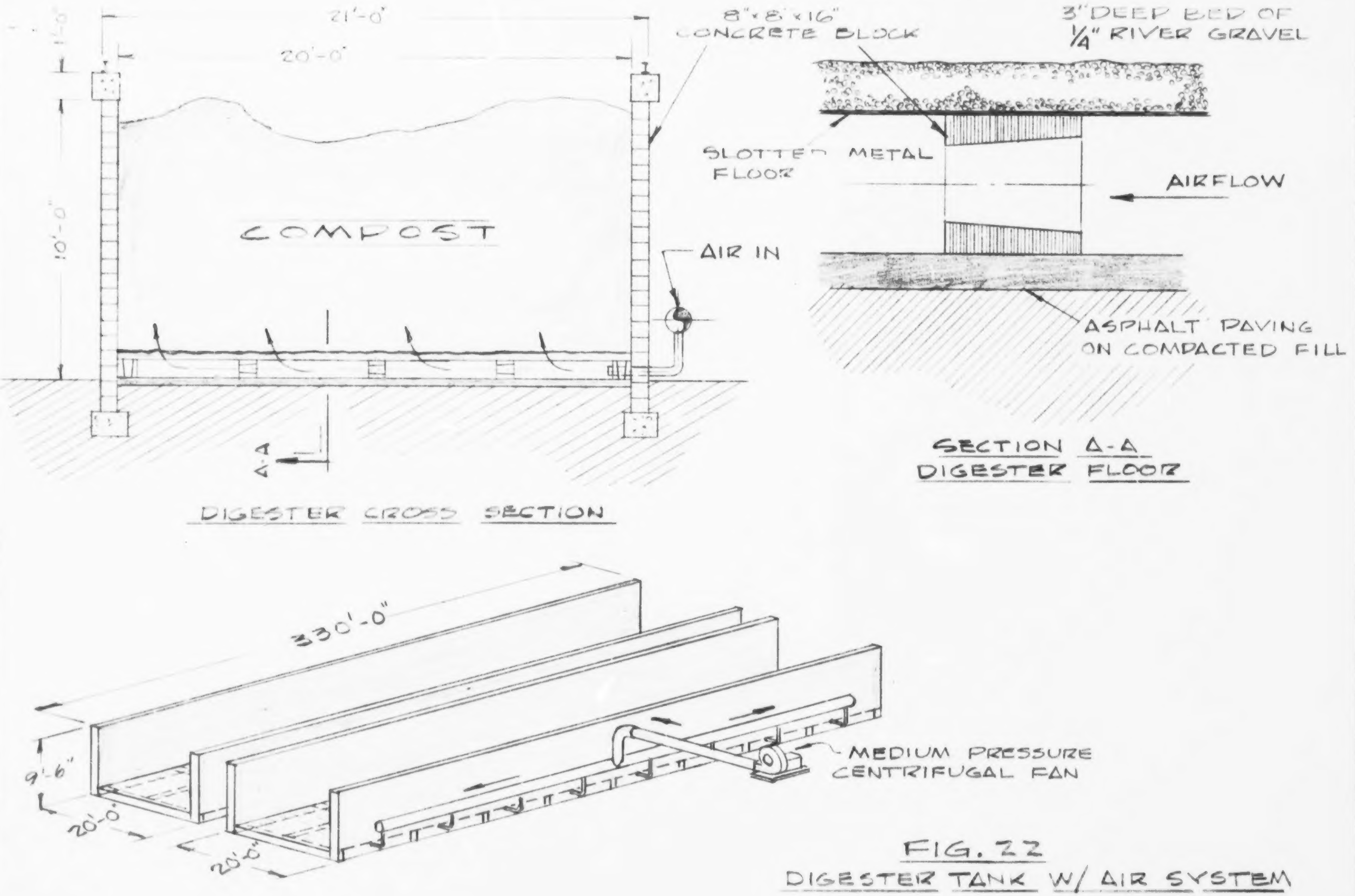

21'-0"
20'-0"
1'-6"
10'-0"
8"x8"x16" CONCRETE BLOCK
COMPOST
AIR IN
A-A
DIGESTER CROSS SECTION
3" DEEP BED OF 1/4" RIVER GRAVEL
SLOTTED METAL FLOOR
AIRFLOW
ASPHALT PAVING ON COMPACTED FILL
SECTION A-A
DIGESTER FLOOR
330'-0"
9'-6"
20'-0"
20'-0"
MEDIUM PRESSURE CENTRIFUGAL FAN

FIG. 22
DIGESTER TANK W/ AIR SYSTEM

evenly along the bottoms of the digestors from where it rises somewhat uniformly through the composting refuse. Air is forced through the air slots on a timed cycle. The refuse is distributed to the full depth of the tank on top of the gravel for its digestion.

6. Air System

Air is blown through a system of ducts to a plenum under the perforated floor by a low pressure centrifugal fan. There is one fan for each of the two digesters. These fans are rated at 5,000 CFM at a static pressure of 9.0 inches of water. They are powered by 15 HP electric motors. Each motor is controlled by a timing device which provides five basic time ranges with a cycle change every 15 minutes. Each digester is divided laterally into two sections. Air is forced alternately into one section and then the next. The timing of the aeration cycle is adjusted to keep an oxygen residual in the refuse ranging from 5 - 10 percent. Each digester section is divided into eight 20 ft subsections each served by two air inlets from the main duct work. Air into one subsection is more or less prevented from moving into another one by concrete block beneath the perforated floor. This tends to balance the air supply throughout each digester section. The fans were manufactured by Peerless Electric Division of H. K. Porter Company, Inc. of Warren, Ohio. The floor plates were manufactured by Pennington Manufacturing Company, Addison, Illinois.

7. Agi-Loader (Figure 23)

The Agi-Loader has two functions: 1) to agitate the composting refuse in the digester tanks, and 2) to unload the material from the tanks. The Agi-Loader was designed by Metro-Waste (Patent No. 3,294,491), and manufactured by Gulf Machinery Company, Safety Harbor, Florida, Model No. 71-11. The machine has two basic parts: 1) an apron conveyor 19 feet wide by 19 feet long, and 2) a shuttle belt conveyor with folding ends. The shuttle belt is 24 inches wide by 24 feet long. It is driven by a 1 1/2 HP motor and has a belt speed of 260 feet per minute. The apron conveyor is driven by a 7 1/2 HP electric motor and has a constant speed of 25 feet per minute. Both conveyors are mounted on a framework which rolls on rails mounted on top of the digester tank walls. The Agi-Loader has two independent drives to move it on the rails. The forward feed drive is used for slowly moving the machine when the apron conveyor is agitating or unloading compost. This drive is a Boston "Ratiotrol" unit, manufactured by Boston Gear Works, Quincy, Massachusetts, Series E. Model SCR. It consists of a 1 HP D.C. electric motor which is variable in speed but constant in torque output. The motor uses a rheostat type control for the

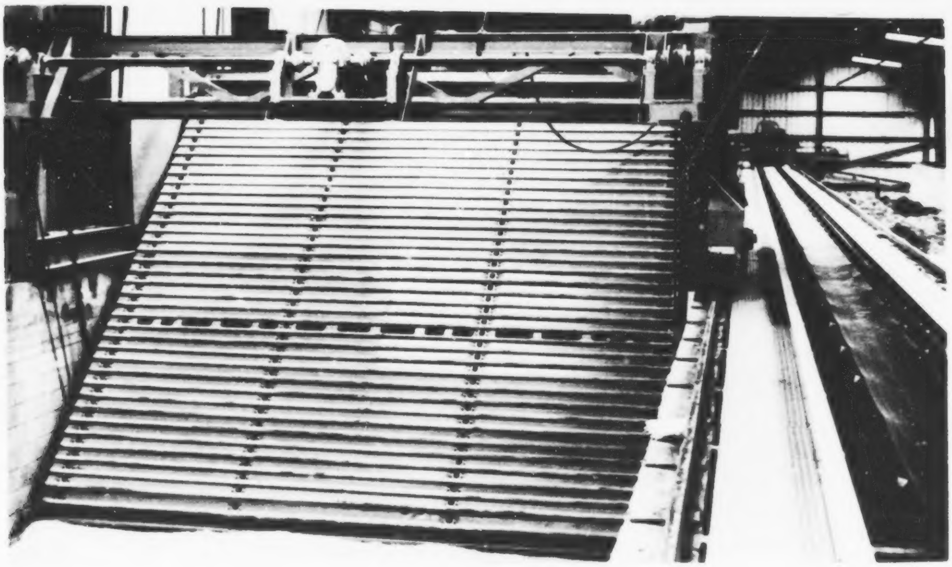


FIGURE 23

Agi-Loader

speed variation. The 1 HP motor drives a 3600-1 ratio gear reducer. The working rail speed of the Agi-Loader is from 0.30 inches per minute to 9.04 inches per minute.

A second Agi-Loader drive is called the "quick return" drive. It is used to move the machine to the end of the digester tank. The quick return drive gives a rail speed of 60 feet per minute and is driven by a 2 HP gear motor. The apron conveyor is pivoted at the drive end or top, while the bottom can be raised or lowered using a cable-operated winch, driven by a 5 HP gear motor. During agitation, the apron conveyor is lowered into the digester until it just clears the gravel at the bottom. The Agi-Loader moves slowly forward against the compost with the apron conveyor lifting the compost out of the digester and carrying it to the top end of the conveyor where it falls back into the tank. During agitation the unloading shuttle conveyor is rolled out of the way so the compost can fall directly back into the tank.

Agitation aids digestion in several ways: it breaks up any air channels in the mass; it relieves a settling or packing condition which hinders aeration from the floor plenums, it provides additional mechanical aeration of the composting mass, and it disperses microorganisms more uniformly through the digesting mass.

To unload the digester tank using the Agi-Loader, the same process is used as in agitating except the shuttle conveyor is rolled forward to catch the compost falling from the top end of the apron conveyor. The shuttle unloading belt then conveys the compost to the tripper belt where it is carried to the digester unloading belt.

The digester tank can be filled at the same time it is being emptied using the same tripper-belt provided the tripper is located "upstream" of the Agi-Loader on the tripper belt.

Unfortunately, in practice, the Agi-Loader could not unload the digesters as fast as it was designed to do. This forced it to be used solely for unloading the digesters.

8. Transfer Car

With an interest in economy, only one Agi-Loader is used for both digester tanks. The Agi-Loader can be transferred from one digester tank to the other by using a Transfer Car System at the unloading end of the digesters. The transfer car is a platform which travels on rails between the digester tanks and is itself equipped with rails on which the Agi-Loader is positioned during the transfer operation.

To move the Agi-Loader from one digester tank to the other, the apron conveyor must first be raised out of the digester tank. Then the Agi-Loader is driven on to the transfer car, which moves by lowering the apron conveyor into the composting material. The transfer car is driven by a 3 HP gear motor and has a rail speed of about 45 feet per minute.

H. FINISHING SYSTEM

1. Discharge Conveyor System

After the refuse has been digested, it is discharged from the tripper conveyor onto the Discharge Unloading Belt. This belt runs from the tripper conveyor belt underneath the transfer car rails and discharges onto the Final Grind Feed Belt. The Discharge Unloading Belt was manufactured by Gulf Machinery Company, Safety Harbor, Florida, Model No. 74-34. It is 24" wide by 35" long and is driven by a 2 HP motor giving a final belt speed of 250 feet per minute.

The Final Grind Feed Belt elevates the compost to the Grinder Feed Screw. This belt is 24 inches wide by 49 feet long, and is driven by a 3 HP motor and has a belt speed of about 250 feet per minute. The Belt and Grinder Feed Screw were both manufactured by Gulf Machinery Company, Safety Harbor, Florida. The Belt Model No. is 74-35, and the Screw Model No. is 74-36. The Grinder Feed Screw is 16 inches in diameter and 24 feet long and is driven by a 3 HP motor at 90 RPM.

From the Final Grind Screw the compost drops into two identical Grinder Metering Screws. Each of these is 12 inches in diameter and 7 1/2 feet long, and is driven by a 1 HP motor giving the screws a speed of 110 RPM. They were manufactured by Gulf Machinery Company, Safety Harbor, Florida, Model No. 74-37.

Although each final grind mill is rated at 10 tons per hour, an overflow screw conveyor is provided at the end of the final grind screw to return the possible overage to the Final Grind Feed Belt.

2. Final Grind Mills (Figure 24)

These mills are fed at the top, and the compost is dropped into a set of fast turning horizontal swing hammers or blades, which are turned by a vertical main center shaft. The material is forced between the hammers and stationary screens which are 3 feet in diameter with 9/16 inch perforation on 3/4 inch centers, providing an open area of 51 percent, which creates a shearing action. These mills are made by Dan B. Vincent, Inc., Tampa, Florida. They are about 36 inches in diameter by 30 inch screen height, and weigh about 8,000 pounds. They are powered by 150 HP motors, with a shaft speed of about 960 RPM. As the compost becomes fine enough, it is discharged through the circular screen at the periphery. The regrind mills are in a vertical position and the discharge is at the bottom. The finely ground material is carried by the Grinder Discharge Screw Conveyor to the Stockpile Conveyor. The Grinder Discharge Screw is 24 inches in diameter by 20 feet long, is driven by a 5 HP motor, and rotates at about 26 RPM. It was manufactured by Gulf Machinery, Safety Harbor, Florida, Model No. 74-28.

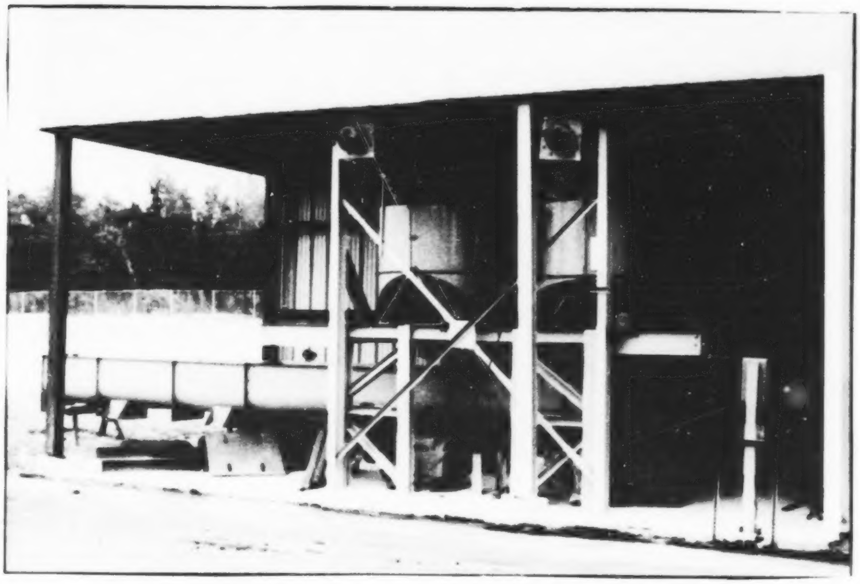


FIGURE 24

Final Grind Mills

3. Stockpiling (Figure 25)

From the Grinder Discharge Screw, the compost drops onto the Stockpile Conveyor. This Conveyor is 18 inches wide by 80 feet long, and elevates the compost to about 35 feet above the ground at the rear of the Bulk Storage Building. As a pile is formed under the end of the belt, the end-loader can carry the compost into the storage building for stockpiling or for out-loading. There is a concrete loading ramp in the building for ease of truck loading.

The use of the final grinders was discontinued during the last quarter of 1969 for a number of reasons. A hole was cut in the final grind feed screw to let the compost fall to the ground before it got to the final grinders. The compost was then moved to storage areas with the end-loader.

I. MACHINERY AND EQUIPMENT SPECIFICATIONS

Appendix A gives a complete breakdown on each piece of equipment and its specifications. This shows the equipment only that was in operation at the close of the grant period.

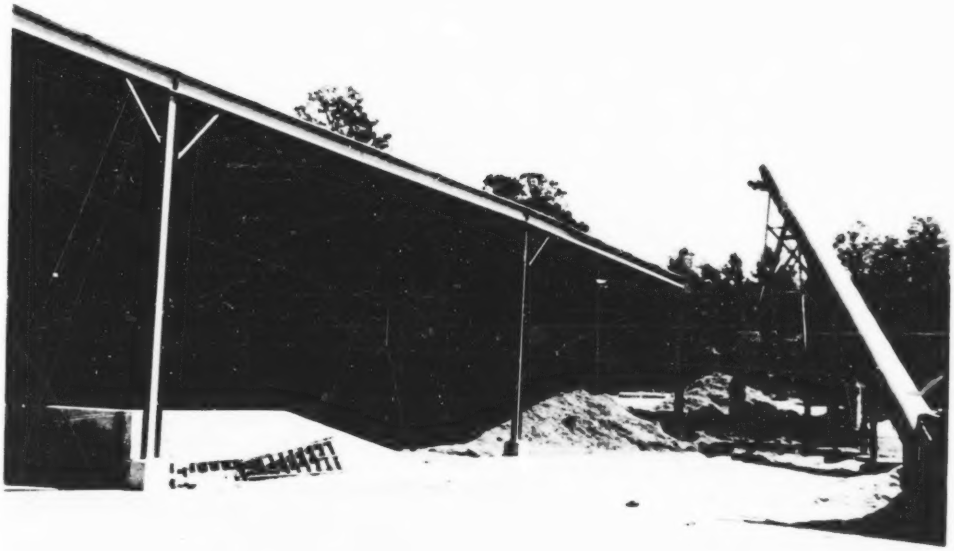


FIGURE 25

Stockpiling

APPENDIX A

MACHINERY AND EQUIPMENT SPECIFICATION TABLE
GAINESVILLE MUNICIPAL WASTE CONVERSION AUTHORITY, INC.

Description and Size	Manufacturer or Supplier & Model No.	H.P.	RPM of Screw, driver or head pulley	Dia. in inches of head pulley or screw	Belt Speed in feet per minute	Capacity Designed	Belt width
Receiving Apron Conveyor 12'-0" x 66'-0" x 12'-6"	Gulf 74-6	2	1/3 - 3	23½	2 - 20	60 tons	12'0"
Oscillating Conveyor 63" wide x 18" deep x 20'0" long	Link-Belt 74-22	10	200 cycles per min. 7/8" stroke			20 TPH	
Sorting Conveyor 60" x 83'-0"	Gulf 74-23	5	5 - 15	24	10-30	40 TPH	60"
Newsprint Conveyor 48" x 16'-0"	Gulf 74-42	1	25	12	80	40 TPH	48"
Cardboard Conveyor 48: x 16'-0"	Gulf 74-47	1	25	12	80	40 TPH	48"
Baler Conveyor 36" x 15'-0"	Gulf 74-43	1	25	12	80	30	36"
Baler (bale size 30"x42"x60" long	Maren 72-5	20				(5) bales (900-1000lbs) per hr.	
Crusher Disintegrator Crusher Section (2) Apron Conveyors 48" x 7'-0" Each of (2)	Centriblast (Joy) CDN-4824-HD	300	1000 RPM Hammer Shaft			20 TPH	
		7½	11.25 RPM Star Shaft	12.94 Apron Sprocket	46.2	20 TPH	48"
		7½	13.5 RPM Driven Shaft Each Apron	12.94 "	46.2		
Belt Slinger 30" wide	Stephens - Adamson 30" car loader	7½	520-1560	10	1500-3500	20 TPH	30"

TABLE OF APPENDICES

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APPENDIX A Continued

Description and Size	Manufacturer or Supplier & Model No.	H.P.	RPM of Screw, driver or head pulley	Dia. in inches of head pulley or screw	Belt Speed in feet per minute	Capacity Designed for	Belt Width
(4) Centrifugal fans on ballistic separator	Sheldons No.13 W/xB Wheel	15 15 15 15	613 - 1560	12		10,000 cfm at 9" SPH$_2$O	
Non-compostable or Upper Discharge Belt 30" x 23'-0"	Gulf 74-25	1	38	14	106	0.4 TPH	30"
Intermediate or lower discharge belt 60" x 46'-0"	Gulf 74-24	5	30	20	150	20 TPH	60"
Secondary Grinder	Williams GA 70	400	1200			20 TPH	
Mixing Screws (2) 34" x 12'-0"	Gulf 74-29	3 3	45 45	16 16		20 TPH	
Transfer Belt 30" x 26'-0"	Gulf 74-20	2	56	18	250	60 TPH	30"
Magnetic Separator	Eriez SE-1300	3		24			30"
Can Conveyor 12" x 48'-0"	Gulf 74-31	2	33	12	100	24 TPH	12"
Can Conveyor 16" x 40'-0"	Gulf 74-28	2	33	12	100	30 TPH	16"
Sludge Pump at Sludge Tank	Moyno SWG8	3				10-50 GPM	
Sludge Aeration Blower	Sutorbuilt No. 3H	3	1670 167			42 cfm @ 2.5 PSI	
Tripper Belt Conveyor 22" x 300'-0"	Gulf	7½			450	20 TPH	22"
Tripper Drive and	Gulf	1			50		
Tripper Shuttle Conveyor 18" x 20'-0"	74-40 (modified Link-Belt)	1	74	12	475	40 TPH	18"

Description	Manufacturer or Supplier & Model No.	H.P.	RPM of Screw, driver or head pulley	Dia. in inches of head pulley or screw	Belt Speed in feet per minute	Capacity Designed for	Belt Width
Digester Unloading Belt 24" x 35'-0"	Gulf 74-34	2	60	16	250	60 TPH	24"
Agi-Loader 19'-0" x 19'-0" Apron Conveyor 19'-0" x 19'-0"	Gulf 71-11	7½	4	23½	25	140 TPH	19'-0"
Shuttle Conveyor 24" x 24'-0"		1½	61	12	260	200 TPH	24"
Quick Return		2			Rail Speed 60 fpm		
Forward Feed		1 DC			Rail Speed 9.04"to 30"pm		
Hoist Drive		5					
Final Grinder Feed Belt 24" x 49'-0"	Gulf 74-35	3	60	16	250	60 TPH	24"
Grinder Feed Screw 16" x 24'-0"	Gulf 74-36	3	90	16		40 TPH	
Grinder Regulator Feed Screws 12" x 7'6" (2)	Gulf 74-37	1 1	110 110	12 12		20 TPH 20 TPH	
Final Grinders (2)	Vincent VG 150	150 150	960 960			10 TPH 10	
Grinder Discharge Screw 24" x 20'-0"	Gulf 74-28	5	26	24		40 TPH	
Stockpile Conveyor 18" x 80'-0"	Gulf	5	60	12	250	30 TPH	18"
Air Compressor	Worthington	3					

Description	Manufacturer or Supplier & Model No.	H.P.	RPM of Screw, driver or head pulley	Dia. in inches of head pulley or screw	Belt Speed in feet per minute	Capacity Designed for	Belt Width
Agi-Loader Transfer Car	**Gulf**	3			45 fpm **Rail Speed**		
Building Ventilator Fans (3)	**Ilg.** U-PDE 485	5	900			**30.700cfm@** **1/8"SPH$_2$O**	
Digester Blowers (2)	**Peerless** **K1047**	15	1750			**5,000cfm @** **9.0"SPH$_2$O**	
Grinder Feed Screw Overflow Screw Conveyor 12" x 36'-0"	**Link-Belt**	5					
Truck Scale	Toledo 2781			60'-0" x 10'-0" Platform		50 ton	
Oscillating Conveyor * 12' x 62" x 18"	Link Belt Type C	10	1200 1" Stroke			30 ton	
Primary Grinder *	Williams #460 Tube K	400	900			35 ton	
Magnetic Separator* 70" x 115" x 38"	Eriez SE-555						

* New equipment installed in June, 1969 after Contriblast was removed.

Description	Manufacturer or Supplier & Model No.	H.P.	RPM of Screw, driver or head pulley	Dia. in inches of head pulley or screw	Belt Speed in feet per minute	Capacity Designed for	Belt Width
Agi-Loader 19'-0" x 19'-0" Apron Conveyor 19'-0" x 19'-0"	Gulf 71-11	7½	4	23¼		140 TPH	19'-0"
Shuttle Conveyor		1½	61	12		200 TPH	24"
Quick Return		2			Rail Speed 61 fpm		
Forward Feed		1 DC			Rail Speed 9.04"to 30"pm		
Hoist Drive		5					
Final Grinder Feed Belt 24" x 49'-0"	Gulf 74-35	3	60	16	250	60 TPH	24"
Grinder Feed Screw 16" x 24'-0"	Gulf 74-36	3	90	16		40 TPH	
Grinder Regulator Feed Screws 12" x 7'6" (2)	Gulf 74-37	1 1	110 110	12 12		20 TPH 20 TPH	
Final Grinders (2)	Vincent VG 150	150 150				10 TPH 10	
Grinder Discharge Screw 24" x 20'-0"	Gulf	5	26	24		40 TPH	
Stockpile Conveyor 18" x 80'-0"	Gulf	5	60	12	250	30 TPH	18"
Air Compressor	Worthington	3					

V. CONSTRUCTION AND COSTS OF PLANT

A. CONSTRUCTION

Construction of the plant began on March 27, 1967, following a period of approximately three months for receiving bids and reworking part of the plans. Construction covered the following phases:

1. Site preparation
2. Office building foundations and construction
3. Plant building foundations
4. Erection of main building
5. Construction of digesters
6. Plumbing and sheet metal work
7. Machinery foundations
8. Installation of plant machinery and equipment
9. Electrical installations
10. Sewage sludge handling facilities
11. Scale installation
12. Final grading and road installation

B. COST OF PLANT AND EQUIPMENT

The plant as originally designed had several changes before the final grant period came to an end - (December 31, 1969). The costs outlined below include only the equipment and buildings as finally used at the end of the operating period.

1. Land, land improvements, and site preparation, including site clearing, grading, black top paving, drain tile, fence, etc.	$105,162
2. Buildings:	
a. Office and Laboratory	23,124
b. Plant Buildings	107,455
c. Bulk Storage Building	13,400
3. Machinery and Equipment:	
a. Receiving System:	
1. Truck Scale	21,972
2. Receiving Ramp, Drive	48,640
3. Apron Conveyor	30,745
4. Oscillating Conveyor	10,192
5. Picking Belt	13,236
6. Picking Platform and Control Tower	25,878
b. Paper Salvage System:	
1. Baler	8,006
2. Conveyor	10,667
c. Grinding System:	
1. Williams Hammermill (#460-Type K)	30,351
2. Oscillating Conveyor	6,220
3. Electromagnet	7,600
4. Transfer Conveyor	15,039
5. Williams Hammermill (GA-70)	21,062
d. Sludge Handling System:	
1. Mixing Screws	2,981
2. Sludge Tank	12,200
3. Sludge Pump	2,140
4. Sludge Blower	378
e. Digester System:	
1. Tripper Belt Conveyer	13,815
2. Tripper - unloading conveyor	3,139
3. Digesters and air system	40,535
4. Agi-Loader and Transfer Car	39,664
5. Conveyors	13,833

f.	Finishing System:	
	1. Final Grinders	24,992
	2. Conveyors and Miscellaneous	19,184
	3. Stockpile Conveyor	5,242
4.	Electrical, Plumbing, Heating and Air Conditioning	169,388
5.	Erection and Installation of Machinery and Equipment:	
	a. Supplies and services	70,910
	b. Labor and Payroll Expenses	134,202
	c. Supervision and Sundry Expenses	58,000
6.	Front-End Loader	18,282
7.	Fork Lift	7,106
8.	Station Wagon	3,472
9.	Tools	7,239
10.	Supplies - Baling Wire	2,355
11.	Office and Laboratory	
	a. Office Equipment and Furnishings	3,155
	b. Office Supplies	2,080
	c. Laboratory Equipment	11,391
	d. Laboratory Supplies	2,939
12.	Consultants	
	a. Engineering, Design and Inspection	67,809
	b. Technical	13,902
13.	General and Administrative Expense	47,150
	Total Cost	$1,296,232

VI. TRAINING AND EARLY OPERATION

A. PRELIMINARY EQUIPMENT TESTING

As construction work neared completion and each piece of machinery was completely installed, it was started up and run for a period of time without any load. This was to insure proper functioning of all components, including bearings, gears, belts, mounting, power, etc. After this initial testing, small quantities of refuse were brought into the plant, not only to test the machinery under load, but also to train personnel in the proper operation of the equipment. The quantity of refuse for processing increased each month from January to March. By April 1, 1968, most of the problems had been resolved except in the area of the primary grinder, so it was decided to have the City deliver their full capacity. The County started their deliveries on April 9, 1968 and the University of Florida started delivery of their solid waste on June 1, 1968.

B. PERSONNEL TRAINING

Probably the most critical part of the plant start-up was in personnel training. This was one of the reasons for a prolonged shakedown period. The plant superintendent had an extensive training period of approximately six months at Metro-Waste's Houston, Texas Plant. He returned to Gainesville in time for final assembly of machinery and components.

C. PERSONNEL REQUIREMENTS

The original estimate of the number of personnel required to operate the plant was quite accurate. The original estimate of 25 persons was increased to 26, including supervisors and management-level personnel. Table A shows personnel positions and salaries or wages required to operate the plant when it is processing 150-160 tons of refuse per day.

TABLE A

PERSONNEL POSITIONS AND SALARIES

I. Management and Supervisory (48 hours/week)

Position		Monthly Salary*
Project Director		$1,200.00
Secretary - clerk		350.00
Clerk		110.00
Plant Superintendent		850.00
Maintenance Foreman		770.00
Electrician		715.00
	TOTAL	$3,995.00
Average Day**		160.00

II. Hourly Personnel

Position		Number of Employees	Hourly Wages
Maintenance		2	3.15
Welders		2	2.95
Front End Loader		1	2.00
Console Operator		1	1.85
Sorters		6	1.60 - 1.70
Balers		2	1.70 - 2.10
Baler Helper		1	1.60
Tripper		1	1.70
Finishing Operator		2	1.70
Clean-up		2	1.60
	TOTAL	20	$1.60 - 3.15
Average Day**		20	$355.50

* Does not include - Insurance, Workmen's Compensation, etc. Workers are provided 2 weeks paid vacations and 6 holidays each year.

** Calculated using 25 days per month, 9 hours per day.

VII. PERFORMANCE OF EQUIPMENT

Table A summarizes the performance of all major equipment used at the Gainesville Compost Plant or in conjunction with its operation. Most items of equipment as originally installed in the plant did not perform in a fully satisfactory manner. Although this performance was discouraging to project personnel and others served by the plant, it was not unexpected. The State of the Art of composting processes in particular and solid waste handling in general would indicate this. Table A shows the corrective action taken to alleviate the various problems. This information is useful to persons contemplating the use of specific items which were evaluated during the course of this demonstration. In addition, careful study of this equipment performance report will illucidate general principles regarding any equipment which might be used for solid waste processing.

TABLE A

SUMMARY OF EQUIPMENT PERFORMANCE

EQUIPMENT	PROBLEM	SOLUTION
Toledo Truck Scale	1. Faulty card-reader 2. Faulty amplifier 3. Faulty high voltage regulator	1. Replaced faulty parts 2. Minor service needed twice annually
Apron Conveyor	1. Bridging of waste as it falls into oscillating conveyor	1. Filled waste receiving hopper only three-fourths full 2. Installed reversing mechanism on conveyor
Oscillating Conveyor	1. Oscillated too fast, causing motor to overheat	1. Replaced 1800 rpm motor with 1250 rpm motor
Sorting Conveyor	1. Incline on conveyor too steep-waste slips badly, particularly when wet	1. Installed 2" wide strips of rubber belting - 8' on center. This eliminated about 90% of slippage problem.
Paper Salvage System	1. Insufficient storage space in collection conveyor if two types of paper are sequentially baled.	1. Storage space was not increased because mixed paper was baled

TABLE A

SUMMARY OF EQUIPMENT PERFORMANCE
(Continued)

EQUIPMENT	PROBLEM	SOLUTION
Magnet #1 (Eriez - Model SE-555) (New magent used in lieu of ballistic separator)	1. Center pole magnet - excessive belt wear	1. Magnet field should be as wide as the belt to facilitate separation and to reduce belt wear 2. Four belts were worn out in 6 months - reducing belt speed has reduced wear
Primary Grinder (Centriblast)	1. Poor hammer wear	1. Welded on Haynes Stellite tips - built up with "Ultectic" 680 and cap with 4-IP 2. Tried Certanium #707 1/8" (8.76 lbs), #222 3/16" (14.85 lbs), #250 5/32" (5.44 lbs) welding rod 3. Tried nickel manganese tips for wear 4. Centriblast furnished new set of removable hammers (24) and star shaft. New hammers made

TABLE A

SUMMARY OF EQUIPMENT PERFORMANCE
(Continued)

EQUIPMENT	PROBLEM	SOLUTION
Primary Grinder (Centriblast) (CONTINUED)	1. Poor hammer wear	4. of 2% nickel and 15% manganese. 3 tool steel hammers used - shattered under impact of metal. Hammers surfaced with MacKay Hardalloy 58TIC, Certanium, Colmonoy #1, Special Colmonoy #1, Stoody Tube Borium and Stoody #21. These rods wore better, but too expensive to use 5. Final Welding rod used: mangjet 3/16 @.38 per lb for build up, made by Lincoln Elec. Com.; 6-IP 5/32 rod used for capping or hard surfacing @.62 per lb., made by Alloy Rods Co.
	2. Low capacity (designed for 20 tons per hour - only 5 - 10 tons per hour in practice)	1. Increased spacing between hammers and star shaft, 2 additional inches - capacity increased to 12-15 tons per hour

TABLE B

12 MONTH OPERATING COSTS - MAJOR EQUIPMENT

EQUIPMENT	MACHINERY COST	LABOR TO OPERATE	TOTAL COST	TONS PROCESSED	PER TON COST
Front-End Loader	$ 5,840.27	$4,142.00	$9,982.27	43,509	$ .23
Williams (New Primary)*	6,775.08	688.95	7,464.03	20,167	.37
Baler	746.08	3,185.99	3,932.07	1,454	2.70
Williams (Secondary)	12,285.07	688.95	12,974.02	18,971	.68
Tripper	2,427.13	2,453.56	4,880.69	18,971	.26
Agi-Loader	3,542.56	3,085.31	6,627.87	18,971	.35
Regrinders (2)	8,318.89	3,085.32	11,404.21	17,384	.66

* Installed in June - Costs are for six months.

NOTE: These costs are included in all costs shown in Table

X. PAPER AND COMPOST SALES

A. PAPER

Recycling and marketing of paper was a successful operation during the first 1 2/3 years of plant operation. A lot of good quality newsprint and corrugated paper has been received at the plant and as a result a good market developed with the gypsum and roofing industry. Bales were made up with a mixture of newsprint and corrugated with a higher percentage of the latter. This is more desirable for the two industries mentioned due to the higher content of long fibers. An average price of about $17.50 per ton was received during this period. However, from September on to the end of 1970, the market was depressed due to tight money and a slow down in the construction industry. The last price received was $19.00 per ton and tonnage purchased was cut back considerably. Table A shows paper and compost sales during 1968 and 1969.

B. COMPOST

Most of the compost sales have been in the citrus industry in bulk form. This has not been an encouraging picture as only 10% of the compost produced has been sold. Citrus sales were made primarily to 32 different grove managers, in amounts ranging from 13 tons to a high of 400 tons, with tonnage per acre varying from 1 1/2 to 38. The average application was about 3 tons per acre.

TABLE A

PAPER AND COMPOST SALES

Period	Paper Sales						
Month	Amount Tons	Net Income $	Sales Tons	Donations Tons	Total Tons	Tons	Tons
March 1968	33	512		20	20	550	530
April	42	637		2	2	567	565
May	104	1,623	7	20	27	1,022	995
June	67	927		139	139	2,594	2,455
July	56	1,068		102	102	838	736
August	14	260		8	8	0	-8
September	109	2,070	199	96	295	1,066	771
October	132	2,507	205	48	253	1,158	905
November	140	2,732	192	0	192	927	735
December	197	3,835	56	1,106	1,162	889	-273
Total - March - December, 1968	894	16,171	659	1,541	2,200	9,611	7,411
January, 1969	218	4,250	285	43	328	1,561	1,233
February, 1969	197	3,821	353	105		1,348	890
March, 1969	204	3,950	177	2,338	2,515	1,441	-1,074
April, 1969	164	3,220	0	800	800	908	108
May, 1969	163	3,014	89	317	406	1,150	744
June, 1969	96	1,757	211	670	881	1,495	614
July	250	2,666	44	123	167	1,500	1,333
August	272	2,597	109	-	109	1,613	1,504
September	238	1,315	-	-	-	2,283	2,283
October	162	365	613	-	613	2,059	1,446
November	147	538	-	1,002	1,002	3,176	2,174
December	1313	48	238	317	555	4,264	3,709
Totals - 1969	2,242	27,541	2,119	5,715	7,834	22,798	14,964

Transportation, no doubt, was a factor in limiting the amount of compost sold. Hauling distances ranged from 90 to 170 miles from the plant at a cost of from $14.00 to $16.00 per ton delivered and spread on the groves. Of the total Customers, four repeated applications in three consecutive years. Claims were made by these growers that: 1) they had an improvement in the cover crop grown, 2) that the juice content of the product grown had increased, 3) that the yield of fruit per acre had increased, and 4) that it took less time for fruit to reach maturity.

A good percentage of the compost produced was donated to the public participants, mainly the University of Florida, and some to the City of Gainesville in the development of public parks. The University has used the compost as a soil builder, mixing it with sandy soil and amending it with nitrogen, to be used on the ground where new building projects have been completed.

Other areas of compost application have been for pine tree seedlings, truck gardening, and making potting soil blends. One such application with pine tree seedlings was carried on with St. Regis Paper Company in north Florida, where applications were made in various quantities from 3 to 20 tons per acre. Their experience indicated that 10 tons to the acre gave them the best results with the survival rate of seedlings in the test plots exceeding those in the control plots.

Much research needs to be carried on in developing markets for compost. It is planned that as the plant continues to operate, studies and experiments will be carried on where large quantities of compost can be utilized. Two such projects that are planned for Florida are land reclamation and organic farming. Work is already under way in which 100 acres of virtually sterile soil, due to a strip mining operation, will be saturated with compost to try and improve and make the soil productive again. The other project is approximately 400 acres of unproductive, sandy farm soil which will be applied with various tonnages of compost. The compost will be plowed into the soil, left to decompose and crops planted after a year. It is hoped that the results of these tests will develop a future market for compost produced. At the same time the theory of total reutilization of solid waste will become a reality.

TECHNICAL EVALUATION

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TECHNICAL EVALUATION

A. INTRODUCTION

The principal objective of the technical program of the Gainesville Demonstration Project is to provide the technical support required to demonstrate the satisfactory performance of the Metro composting system for the treatment of solid wastes from medium-sized cities. The specific objectives are to:

1) determine what is accomplished by the composting process; and
2) evaluate the public health aspects of the process.

When these objectives were achieved, recommendations in the form of revised operating parameters were made to improve the process. If the operating parameters were revised, their effect on improving the process was subsequently evaluated. Data resulting from the fulfillment of these objectives could be used by:

1) the U. S. Public Health Service to evaluate the utility of composting as a treatment process to partially alleviate the nation-wide solid waste problem;
2) plant operators in the selection of process control parameters to attain more efficient treatment; and
3) technical personnel in control and research work on solid wastes.

During the course of this demonstration project, the Metro composting process, as an example of a high-rate composting system, was evaluated for its utility in the treatment of solid municipal wastes.

B. FACILITIES AND EQUIPMENT

The facilities for conducting the chemical and microbiological studies associated with this evaluation program include a combination chemistry and bacteriological laboratory and special in-plant equipment for monitoring several of the factors which influence the composting process and the quality of the final product.

1. Laboratory

A combination chemistry-bacteriological laboratory is located on site in the compost plant office building. This laboratory has about 360 sq. ft. of floor space and is fully equipped for most of the chemical analyses and all routine bacteriological studies necessary for the demonstration and quality control program. Figure 1 shows a floor plan of the laboratory and the location of the major pieces of equipment. A description of the major laboratory equipment is presented in Table 1.

The staffing of the laboratory varied during the duration of the project. Initially, it was supervised by a part-time professional biologist. He was assisted by a full-time technician and three part-time graduate students, one each to work on the chemical,

TABLE 1

MAJOR LABORATORY EQUIPMENT

Item	Manufacturer	Model No.
1. Drying Oven	Precision Thelco	27
2. Analytical blance	Mettler	H-15
3. Water Still	Barnstead	EMH-5
4. Water bath	Precision	66634
5. Steam Generator	Amsco	LB20
6. Glassware washer	Heinicke	HW200S
7. pH Meter	Sargent	PL (No.30008)
8. Kjeldahl Unit	Labconco	20701
9. Moisture Balance	Ohaus	6010
10. Induction Furnace	Leco	521-000
11. Klett Industrial Photometer	Klett	900-3
12. Autoclave	Scanlan Morris	A-422
13. Incubators (2)	Precision Thelco	4
14. Mikro-Samplmill	Pulverizing Machinery Div. Metals Disintegrating Co., Inc.	-
15. BOD Incubator		
16. Andersen Air Sampler	Andersen Samplers and Consulting Service	-

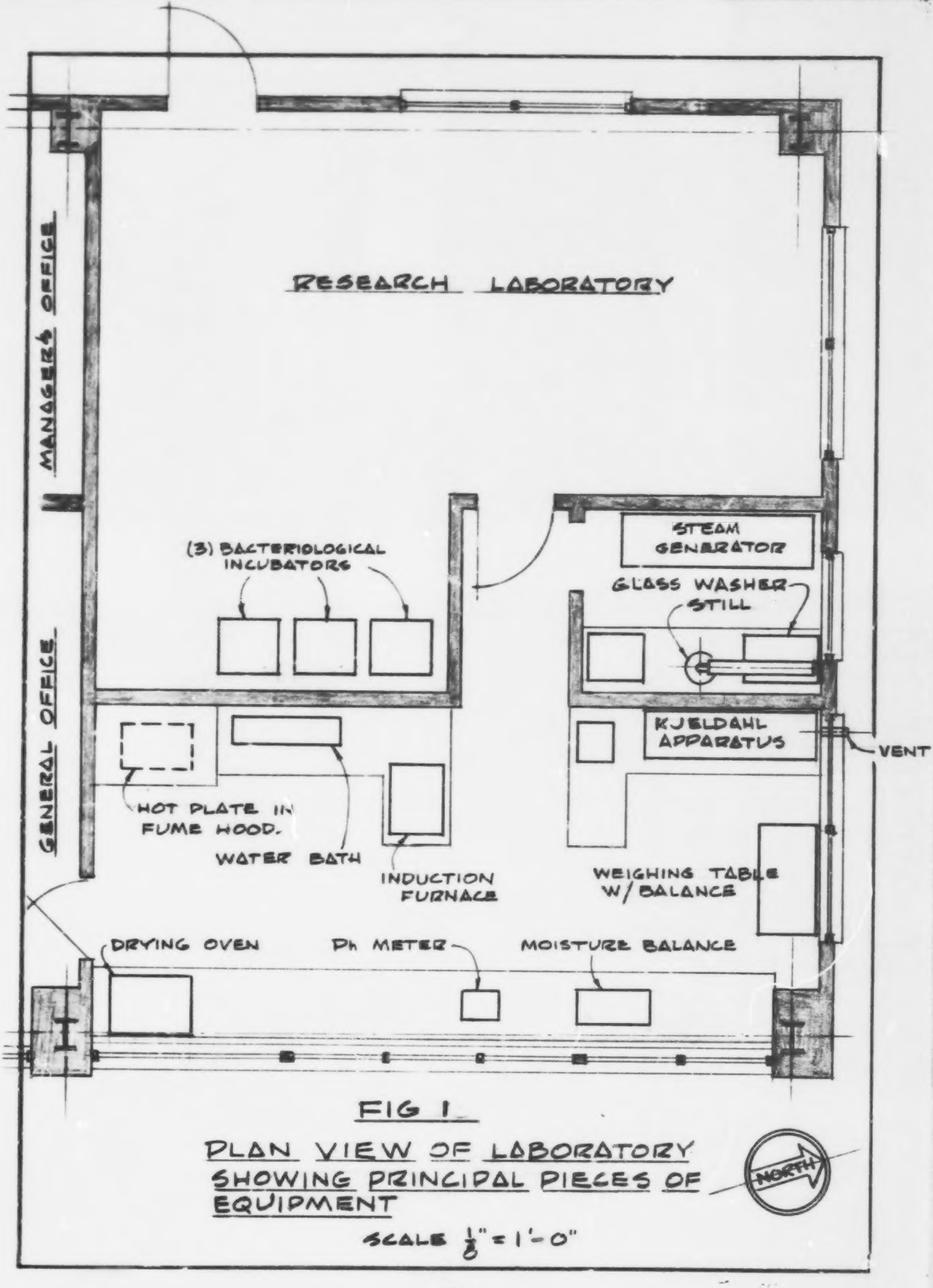

RESEARCH LABORATORY
MANAGER'S OFFICE
GENERAL OFFICE
(3) BACTERIOLOGICAL INCUBATORS
STEAM GENERATOR
GLASS WASHER
STILL
KJELDAHL APPARATUS
VENT
HOT PLATE IN FUME HOOD.
WATER BATH
INDUCTION FURNACE
WEIGHING TABLE W/ BALANCE
DRYING OVEN
Ph METER
MOISTURE BALANCE
NORTH

FIG 1

PLAN VIEW OF LABORATORY SHOWING PRINCIPAL PIECES OF EQUIPMENT

SCALE $\frac{1}{8}$" = 1'-0"

bacteriological, and arthropod and rodent control aspects. Staffing of the technical evaluation program was continually enlarged until it included a full-time director who was a professional microbiologist, a full-time graduate engineer, a full-time technician, and two half-time technicians.

2. Process Control and Special Studies Equipment

The compost plant is equipped so that the moisture content of the ground raw refuse and the temperature of each batch of compost in the digester tanks are continuously monitored. In addition to the continuous monitoring equipment, a special mobile instrument package was developed by Honeywell, Inc., to measure the temperature, dew point, O_2 content, and CO_2 content at several levels anywhere in the digester tank, and also to measure the volume of air entering a segment of the digester tank.

3. Moisture Sensor

The moisture content of the ground refuse was measured as a function of the conductivity between two sensing electrodes in an A.C. bridge circuit. The signal generated by this circuit is calibrated in terms of moisture content and is recorded on a circular chart recorder.

The sensing electrodes consist of two metal shoes 1 1/4 inches wide and 4 1/4 inches on center. These sensors are on a pivoted arm that rides on the surface of the ground refuse as it is conveyed from the mixing screws following the secondary grinder to the digester tanks. The electric signal from these electrodes activates a variable speed pump which supplies either water or sewage sludge to the refuse in the mixing screws in order to maintain a pre-selected moisture content in the ground refuse. A limit switch is connected in the circuit so that if no compost is on the conveyor belt (i.e., the electrodes pivot down to the surface of the conveyor belt) the pump will not operate.

The specific components of this system were itemized in a previous report(1).

4. Temperature Sensor Probes

As described in a previous section of this report, the composting process is a batch-type operation with each batch consisting of the refuse from one day's operation. This batch is placed in the digester tank where it remains for a six-day digestion period. During the digestion period, except for the short period when the compost is agitated, the temperature of each batch is continuously monitored with a copper-constative thermo-couple sensing probe, 24 inches long, which is inserted horizontally into the pile through an opening in the digester wall. The probe is withdrawn when the batch is agitated and then reinserted immediately upon completion of this operation.

There are four such temperature probes in each digester, located at the quarter points of the digester length. The temperatures recorded at the eight locations are recorded on an eight point strip chart recorder.

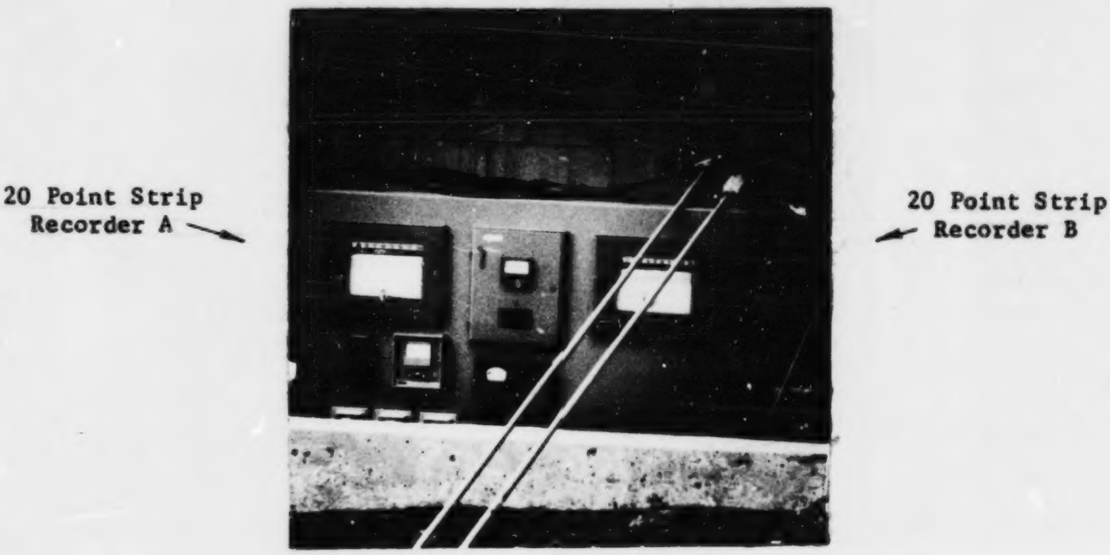
The specific components of this system were itemized in a previous report(1).

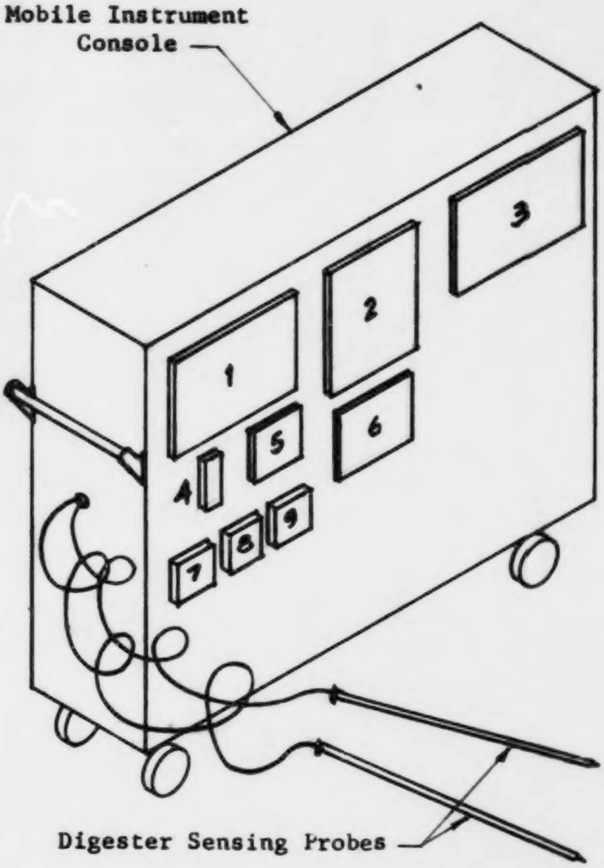
5. Mobile Instrument Console

A new and unique instrument package has been developed for the Authority by Honeywell, Inc. This is a Mobile Instrument Console package, shown in Figure 2 , which can travel the length of the west digester tank. It is equipped with one probe to measure temperature at five levels, and dew point, O_2, and CO_2 at four levels in the compost pile. A second probe measures temperature only at five levels. A third component of the package is a pressure-sensing unit which can be connected by means of snap-lock fittings to any of sixteen pitot tubes permanently placed in every other air duct which supplies air to the west digester tank. There is also a tap next to each pitot tube for sampling for dew point and the O_2 and CO_2 content of the air being supplied to the digester tanks.

The two probes are constructed of 3/4" diameter fiberglas tubing and have a pointed wooden plug in the bottom end. Both probes have thermo-couples at 6", 24", 48", 72", and 90" from the tip of the probe, and one has gas sampling ports 32", 48", 64", and 90" from the tip.

FIGURE 2


20 Point Strip Recorder A
20 Point Strip Recorder B


Mobile Instrument Console
1
2
3
4
5
6
7
8
9
Digester Sensing Probes

1. Compost Temperature Recorder A
2. O_2 Analyzer
3. Compost Data Recorder B
4. Suction Pump On-Off Switch with Indicator Light.
5. CO_2 Analyzer
6. Inlet Air Volume
7. Signal Transducer for converting signal from O_2 analyzer.
8. Signal Transducer for converting signal from dew probe and ambient temperature thermocouples.
9. Signal Transducer for converting signal from CO_2 analyzer.

FIGURE 2

Mobile Instrument Console

The instrumentation is arranged so that both probes can be used to measure temperature concurrently. The temperature from each of the ten points is recorded on a 20-point strip chart recorder, Recorder A.

The other variables, i.e., inlet air volume, CO_2, O_2, dew point temperature, and also ambient temperature, are measured and recorded on a second 20-point strip chart recorder, Recorder B, which has a stepping switch to operate solenoid values to route the sampled gas stream to the appropriate analytical instrument.

The specific components of the unit are listed in a previous report (1). The cost of this instrument was $15,600 of which about $12,400 was for hardware and the remainder for developmental work and fabrication.

C. METHODS OF SAMPLING

Sampling of raw ground refuse and compost, particularly for chemical analyses, was done by compositing grab samples early in the technical evaluation program. This led to erratic and misleading results. For example, frequently the content of carbon was higher in raw refuse than in compost. This is contrary to fact inasmuch as carbon is expected to diminish as a result of composting. The erratic results were therefore attributable to sampling errors, which in turn are attributable to the extreme heterogeneity of urban solid waste.

An alternative sampling procedure was developed which circumvented the problems of grab sampling. Approximately 0.5 yd^3 of waste was mixed as much as possible without reducing particle sizes. This usually was done with a shovel or fork. One half of the waste was prepared for analysis. A portion of the remainder was placed in a bag made of 16 mesh Fiberglas screen. The bag had an approximate capacity of 1.5 ft^3. The bag was then placed in the digester within the production quantity of waste for treatment. Treatment time and conditions were varied according to need. The bag of waste was retrieved from the digester and prepared for analysis.

Samples before and after treatment were prepared for analysis by passing the waste twice through a riffle sampler (also known as a Jones sampler or sample splitter), having a top opening of 8 x 10 in. and a chute width of 0.75 in. The sample thus reduced in size was dried to constant weight in an 75°C oven. The sample was ground in a Mikro-Samplmill to pass a screen having holes of 0.125 in. in diameter. Subsequently, the sample was reground to pass a screen having rectangular slots of 0.02 in. in width.

D. METHODS FOR CHEMICAL ANALYSES

It was anticipated that chemical analyses would be performed according to the official A.O.A.C. procedures which are commonly used in the inorganic fertilizer industry. Subsequently, the A.P.W.A. procedures(7) were used as a basis from which modifications might be made. It was recognized from the onset of this demonstration that many methods of analyses might have to be modified because of the pioneering nature of this work. The following chemical analyses were performed on compost and refuse during this demonstration: total carbon, total Kjeldahl nitrogen, phosphorus, potassium, moisture, pH, volatile solids, chemical oxygen demand, and biochemical oxygen demand.

1. Carbon

The induction furnace combustion method which is a semi-micro method was used for the estimation of total carbon. The APWA method(7) was used with the following modifications:

a) add a small amount of Alundum to the platinum crucible before putting in samples,

b) use 1.0 N NaOH in place of 0.4N NaOH absorbing solution,

c) digest precipitate in water bath at 70°C instead of at room temperature,

d) use medium porosity glass frit filtering crucibles in place of Gooch crucibles, and

e) dry precipitate overnight at 75°C instead of 1 hour at 105°C.

Toward the end of the demonstration, Ascarite in small absorption tubes was used to collect CO_2 in place of the more cumbersome Ba CO_3

precipitation method. The results were the same, but the procedure was simplified. Analytical precision depends greatly on particle size of the sample. Precision ranged 40 ± 4.7 percent when samples were ground dry in a Waring Blender. Precision ranged 40 ± 1.0 percent when samples were ground on the Mikro-Samplmill to pass a screen having holes of 0.125 in. in diameter.

2. Nitrogen

The Kjeldahl-Wilfarth-Gunning method was used for the determination of organic and ammoniacal nitrogen. A chromium reduction procedure for the determination of total nitrogen including nitrate nitrogen was evaluated. The effect was an insignificant increase in nitrogen and therefore the chromium reduction procedure was abandoned in favor of the APWA procedure(7). Typical analytical precision of the analysis of ground compost was 0.38 ± 0.025 percent; of ground raw refuse - 0.48 ± 0.030.

3. Phosphorus

The APWA method(7) failed to give good results because 25 ml of concentrated sulfuric acid did not completely digest the organic matter and color development was not reproducable. Addition of mercuric oxide to the acid helped to digest the organic matter, but this resulted in a precipitate which interfered with the colormetric determination.

Complete digestion of organic matter was accomplished by the following combinations of reagents: 1) 25 ml concentrated

H_2SO_4, 15 ml concentrated HNO_3 as required, and 2) 25 ml concentrated H_2SO_4 and 2.0 g $K_2S_2O_8$. However, when color was developed with molybdate and done by the APWA method(7), and with S_2Cl_2 by the Standard Methods procedure(8), it was not very reproducable.

The Quimonciac Method(9) was very satisfactory for the determination of phosphate (as orthophosphate) in compost and refuse. In the evaluation of this method the average of 9 determinations was 0.424 ± 0.019 percent phosphate. Recovery of phosphate added to compost averaged 94.4 percent.

4. Potassium

The A.O.A.C. sodium tetraphenylboron method(9) was satisfactory for the determination of potassium. However, it was used on a very limited basis.

5. Moisture

Moisture in refuse and compost was determined by both the oven drying and the infrared methods(7). Samples which were to be analyzed were never subjected to temperatures exceeding 75°C. Data reported on a dry weight basis was calculated from moisture values obtained from oven drying subsamples to constant weight at 103°C.

An Ohaus moisture balance was used for the determination of moisture in samples taken for process control purposes. Moisture values obtained with this instrument were quite reproducible (± 0.5%), and they correlated well with the oven drying procedure. The heat intensity at which samples were dried was not critical. Drying was rapid and the sample weights equilibrated after 20 minutes when the power ranged from 105 - 140 watts. Distance between sample and the lamp was set at 2 in. At 80 watts, drying time was prolonged to 45 min. At 160 watts, drying time was reduced to 15 min., but the sample was scorched.

6. Hydrogen-Ion Concentration

Hydrogen-ion concentrations (pH) were determined by the APWA method(7). However, it is not necessary to use CO_2-free distilled water for suspending the samples if the water is used within 2 weeks after it has been distilled. Furthermore, most raw refuse and compost has considerable buffering capacity.

For routine work, particularly in the field, pH indicator paper was usefull and convenient.

7. Volatile Solids

Volatile solids in samples of raw refuse and compost were determined by the APWA method(7). Although there was no reason to suspect the method for its determination, volatile solids data were never reliable as an indicator of loss of putrescible matter as a result of composting. It would appear that volatile solids data are an excellent indicator of putrescible matter loss because they approximate organic matter loss. Apparently, the lack of reliability is attributable to sampling errors.

8. Chemical Oxygen Demand

The determination of chemical oxygen demand (COD) of solid materials is similar to that of liquids except that a wetting agent is required to obtain a reasonably uniform suspension of solids for subsequent sampling and dilution. The most accurate and precise results were obtained when using Aquarex (DuPont) as a wetting agent. A 1.8% solution of this material is made up with distilled water. A 0.5 g sample of ground compost or refuse is weighed and placed in an 800 ml beaker with a magnetic stirring bar. Samples were ground with a Mikro-Samplmill to pass a screen having holes of 0.125 in. in diameter. One-hundred ml of the 1.8% solution of Aquarex is added and the mixture is stirred until all the compost is wetted. This usually occurs in a minute or so. Four-hundred ml of distilled water is added and stirring is continued. A 10 ml Mohr pipet with the tip enlarged is used to take the sample. The sample (10.0 ml) is placed into the COD flask. From this point the procedure is the same as that found in Standard Methods(8). An equivalent quantity of Aquarex is used in the blank. Therefore, subtraction of the COD value of the blank from the COD value of the sample containing the wetting agent gives the COD value of the sample only.

9. Biochemical Oxygen Demand

The determination of biochemical oxygen demand (BOD) of solid materials is similar to that of liquids. Just as in the

COD determination the solids must be uniformly suspended in a liquid for accurate sampling and dilution.

The oven dried waste (5.00 g) is homogenized for 5 minutes with 495 ml of BOD dilution water in a Waring blender. Raw ground refuse and compost can be satisfactorily homogenized with the Waring blender. It is not necessary to fine grind these materials. This suspension was subsequently diluted in the same manner as a liquid waste. Following this preparation, the analytical procedure is similar to that described in Standard Methods(8). Fresh sewage is used as seed after storage for 24 - 48 hrs. at 20°C. It is filtered through Whatman No. 12 paper to remove suspended solids. The seed is used at a concentration of 10 ml per liter of suspended waste. This high concentration is always desirable, but it is necessary if the waste had been dried previous to analysis.

The BOD test has many disadvantages even when used for the analysis of liquids. The disadvantages are compounded when the test is used for the analysis of solids. Among these are the long incubation period, poor precision, and the fairly involved procedure. However, the BOD test proved to be the most reliable one for determining the reduction of putrescible matter resulting from composting.

The advantage of the BOD test is that it is a measure of the carbon which is available for biological utilization. This is important because composting is a biological degradation process.

Consequently, the BOD value of raw solid waste is an approximation of the carbon compounds which could be decomposed by composting. Also, the BOD value of composted waste is an approximation of further decomposition potential. It is this decomposition potential which leads to odors when an immature compost becomes wet. The difference between BOD values before and after composting is a measure of what was accomplished during composting.

It appears, therefore, that there is a need for a method for the determination of carbonaceous matter which can be utilized by biological systems.

10. Putrescible Matter

One of the more vexing problems facing researchers in solid waste treatment is the lack of methods for the determination of biological stability of waste, i.e., its content of putrescible matter. Process evaluation at the Gainesville plant and elsewhere depends on knowing the stability of the waste at various stages of treatment. With this knowledge it is possible to determine the efficiencies of various processes.

Waste stability at Gainesville was determined by the following tests: the standard BOD, the Hach modification of the BOD, the COD, volatile solids, and C/N ratio. None of these tests was fully satisfactory for various reasons. This shortcoming usually necessitated making all analyses on each sample.

A reportedly rapid, simple, and inexpensive method for the determination of the completion of composting was evaluated for applicability. Jann(12) and others developed the method to determine the quantity of the putrescible matter in organic wastes. Their method is based on the principle that volatile acids are produced during the anaerobic decomposition of fresh raw organic matter. On the other hand, stable organic matter subjected to anaerobic conditions fails to yield appreciable quantities of acid because the acid precursors have been decomposed previously. Generally, their method involves the incubation of a 5.0 g sample in a screw cap tube at 55°C. The pH of the sample is determined at 0, 24, 48, and 72 hours. The completion of composting is indicated by a pH of 7.5 after the sample has been held anaerobically for 24 hours at 55°C. The 48 and 72 hour analyses are confirmatory.

The test was modified somewhat for application to solid wastes which were encountered at the Gainesville plant. Samples were ground on a Mikro-Samplmill to pass a 0.2 mm screen. About 2.5 g of sample were placed in 20 x 100 mm screw top test tubes. Water was added to the tubes to saturate and cover the waste. No further modifications were necessary. The pH of the samples were determined by a meter.

It can be expected that samples representing waste, which had received increasing treatment, would under test produce progressively less acid. This was not always borne out. Sampling errors were shown to be the cause of this inconsistency. A sample of stable compost was tested by this method to give base line data. Putrescible matter at two concentrations was added to the stable compost and the mixture was tested again. The pH which developed on incubation of the samples containing the high concentration of putrescible matter was lower than that of samples containing the low concentration of putrescible matter. Also, the pH which developed on incubation of the latter samples was lower than that developed in unamended samples.

Details on the development of this test for the determination of putrescible matter in compost and refuse were reported previously(6). The work showed that putrescible matter in solid waste can be roughly quantitated on the basis of acid production following anaerobic incubation. Results were available at 24 hours, but verification at 120 hours was desirable. This method was developed late in the Gainesville Demonstration Project and, therefore, was not used routinely in the evaluation of the Metro process. It appears to have the greatest potential of any evaluated on this Project. Further development leading to minor modifications is necessary. What is more important, however, is the repetitive use of the method to establish its reliability.

Variation in subsamples has a profound adverse effect which might be offset by use of much more subsample. Determination of pH by the use of a meter was cumbersome and much more precise than necessary. The use of pH indicator paper would be more convenient and would result in less sample disturbance. The use of inoculum (seed) would probably increase the precision of the test because it is expected that the indigenous microbial population will vary widely among sample types.

E. BACTERIOLOGICAL ANALYSES

Certain bacteriological analyses were made of raw refuse and compost to determine the public health quality of these materials. Selection of these analyses was arbitrary because standard methods for the bacteriological examination of refuse and compost do not exist. Examination for coliform bacteria was accomplished because it is common practice in wastewater technology. Examination for members of the Salmonella genus of bacteria was also accomplished because of the potential this group has for being carried through the food chain of man and animals.

1. Coliform Bacteria

The State of Florida, Department of Health and Rehabilitative Services, required the daily examination of refuse and compost for both total coliforms and fecal coliforms. Samples were taken three or four times each day and composited to represent the entire day. Samples of the material were taken after primary grinding and after final grinding. After considerable experience, the sampling frequency was reduced to twice weekly and the analysis for total coliforms was dropped.

Membrane filtration techniques for the detection of coliforms were unsuccessful because of the particulate nature of the sample. The multiple tube fermentation technique(8) was satisfactory and was used for this purpose on the Gainesville project for about two years. Log dilutions were made from 5.0 g of moist solid material. Transfers of each dilution were made to lactose broth and the confirmed test was carried out. Details of the procedure were previously described (2,3). Numbers of coliforms, the coliform index, was expressed as the most probable number (MPN) on a dry weight basis.

2. *Salmonella*

The State of Florida, Department of Health and Rehabilatative Services, also required the daily analysis of raw refuse and compost for *Salmonella*. The same samples taken for coliform analysis were used for *Salmonella* analysis. Figure 3 shows the screening procedure.

3. Extrinsic Bacteria

The analyses of raw refuse and compost for coliforms and *Salmonella* did not satisfactorily indicate the public health quality of these materials. An alternative procedure was developed.

Raw ground refuse was inoculated with a known number of various pathogenic and heat tolerant bacteria. The ground refuse was placed in a Fiberglas bag and treated in the digester. After treatment, a quantity of the same refuse was recovered and assayed a second time. The numbers of organisms before and after treatment were compared to determine the effect of composting on the growth

FIGURE 3 FLOW SHEET FOR SALMONELLA SCREENING

Each 10 gram Subsample

↓

Plant into≈25 ml. tetrathionate broth

↓ Incubate 48 hours at 37°C

Streak two plates of brilliant green agar

↓ Incubate 24 hours at 37°C

Pink or colorless colonies -
pick to TSI slants
(stab and streak)

↓ Incubate 24 hours at 37°C

Green colonies -
discard as lactose fermenters

Butt acid yellow
Slant alkaline (red)
and/or H_2S+ blackening) -

Inoculate
1. Urea agar
2. Phenylalanine agar
3. Simmons citrate agar

↓ Incubate 24 hours at 37°C

Butt and slant acid (yellow)-
Discard as lactose fermenter

Urea - (no red color) Citrate + blue Phenylalanine - no green color with test reagent Possible Salmonella, re-inoculate TSI slant	Urea+ (red) Citrate + (blue) Phenylalanine (blue to green pigment and grape like odor) discard as Pseudomonas eruginosa	Urea+ Citrate ± Phenylalanine + (green with test reagent) - discard as Providence	Urea+ (red) Citrate + (blue) Phenylalanine + discard as Proteus

↓ Incubate 8-24 hours at 37°C

Proceed with testing for Somatic, "O" antigens with polyvalent "O" antiserum

---

Poly "O" positive
(good agglutination)
Test with "O" groups A1

↓

Poly "O" negative
(no agglutination)
discard as non Salmonella

Probably Salmonella

All groups negative-
Test for washing "Vi" antiserum

"Vi" positive
Boil for 10 minutes to destroy "Vi" antigen then test again for "O" groups A-1

Vi negative
Discard after repeating biochemical and serological tests as non-Salmonella

---

"O" group positive -
Probably Salmonella

Negative -
discard as non-Salmonella after re-testing biochemical and serologic properties

or survival of these extrinsic microorganisms. This procedure yielded information on the effects of composting on a specific, known microorganism.

The test organisms were Escherichia coli, three species of Salmonella, and Bacillus stearothermophilus (American Type Culture Collection No. 7953). E. coli is likely to indicate contamination of intestinal origin, the Salmonellae are important pathogens in the food chain of man and animals, and B. stearothermophilus is an extremely heat tolerant species of bacteria. All organisms were grown on Bacto-Tryptone Glucose Extract Agar (TGEA) to obtain inocula. The organisms were washed off the surface of the agar with a sterile buffer consisting of 1.0 g each of KH_2PO_4 and K_2HPO_4 in 1000 ml of distilled water. This suspension was diluted 1 part by volume into 100 parts of tap water and then mixed thoroughly with about one cubic foot of raw ground refuse. Inoculated refuse (10.0 g) was assayed to determine the initial number of test organisms. The remaining refuse was placed in Fiberglas bags for treatment in the digesters. The 10 g sample was added to 500 ml of buffer and was homogenized in a Waring blender for 5 minutes. Dilutions of this suspension were made and plated on either TGEA to count E. coli and B. stearothermophilus or on Bacto Brilliant Green Agar to count Salmonellae. Plate counts were made in the same manner from compost which had been digested in the Fiberglas bag.

There were several variations made to obtain additional information on the growth of these extrinsic microorganisms in a composting environment. In addition to composting the seeded refuse, refuse inoculated with these pure cultures of Salmonellae, was incubated in the laboratory to determine the effect of lower temperatures on the survival of these organisms in the presence of ground refuse. This was done by incubating approximately 50 g of seeded refuse at 99°F (37°C) in a loosely covered beaker. Counts of Salmonellae were made before and after incubation.

In another variation, refuse seeded with S. paratyphi was subdivided into two quantities. One quantity was placed along the wall of a digester where temperatures are known to be lower than most of the contents of the digester. The temperature rose from 93°F to only 108°F in one day. Another quantity of refuse was placed deep in the digester where temperatures are known to go higher. The temperature of this refuse rose from 93°F to 131°F in one day. After a sample of the first quantity was taken for a plate count determination, it was returned to its original location in the digester for further treatment. The temperature rose from 108°F to 126°F in three additional days.

In a third variation, both spores and vegetative cells of B. stearothermophilus were used to seed refuse. The spores of any organism are expected to be considerably more heat resistant than cells of the same organism. To obtain spores, a culture was allowed to age on TGEA. The spores were washed off the agar with buffer. The buffer suspension was pasteurized at 176°F for 10 minutes to kill any vegetative cells which might not have sporulated. The refuse was then seeded and assayed by plate count in the usual manner.

In a fourth variation, a culture tube containing a buffer suspension of vegetative cells of B. stearothermophilus was placed in the digester for one day. A plate count was made before and after treatment in the usual manner.

During this work, refuse was being moistened with raw sewage sludge except during the one experiment in which refuse seeded with E. coli was composted for 12 days. Bags containing seeded refuse were placed in the digesters at levels ranging from 65 - 80 inches above the bottom. The probable temperature ranges at this level at varying days of treatment are as follows: day 1 - 110-130°F, day 2 - 130-140°F, day 3 - 140-160°F, and day 4 and beyond - 140-160°F.

F. OCCUPATIONAL HEALTH STUDIES

Bacteriological analyses described in the previous section were made principally to show the public health quality of the product. That work delineated potential hazards to the compost consumer. Studies described in this section were made primarily to define potential and actual hazards to plant personnel.

1. Physical Examinations

All plant personnel and most administrative personnel were given periodic physical examinations to detect clinical manifestations resulting from their activities associated with the composting of urban solid waste. It was planned to give the first examination prior to any exposure to solid waste, and then periodically at intervals of 6 months. In addition to general physical examinations, the health of workers was further judged on the basis of the following: Mantoux and histoplasmin skin tests, hematocrit, hemoglobin, and VDRL blood tests, chest x-rays, stool examinations for intestinal parasites, and urinalyses for hydrogen ion concentration (pH), specific gravity, glucose, acetone, protein, and occult blood.

Dr. George Little, a local physician, conducted these clinical studies.

2. Noise levels

Various operations in the processing of refuse for composting generate considerable noise. Two noise level surveys were conducted to determine whether noise was a hazard. A type 1555-A Sound-Survey Meter (General Radio Company) was used for this purpose.

3. Intestinal parasites

The presence of viable parasites in compost would indicate insufficient treatment. Accordingly, samples of raw refuse and compost were examined for parasites.

Samples were collected and sent to the Division of Research and Development, Bureau of Solid Waste Management, Cincinnati, Ohio, for analysis. No attempt was made to cool or otherwise preserve the samples during shipment. Samples were prepared for examination by shaking in the presence of physiological saline and glass beads. Next, samples were either examined directly with a low power microscope or prepared further and then examined microscopically. When further preparation was required, the biological material was separated from debris by either the brine gravity flotation method or Willis(10) or the formalin ether sedimentation method of Ritchie(11).

4. Airborne Particulate Matter

The air in dusty areas of the plant was sampled for particulate matter as an indicator of potential public health hazards. Particulate matter was determined with both a standard high volume sampler for total particulates and with an Andersen sampler to determine particle size distribution.

An 8 x 10" Fiberglas filter was used in the high volume sampler which is 99% effective in removing particles ranging in size from 0.1 micron and larger. The flow rate of air thorugh the instrument was 39.2 cubic ft. per minute. The instrument was placed in the plant midway between the primary and secondary grinders. It was operated for 4 3/4 hrs. in the afternoon of October 17, 1969.

Particle size distribution (weights of particles of various sizes) was determined at two locations in the plant with the Andersen sampler. Two determinations were made on September 8, 1969, at the operators platform. Duration of sampling was one hour in the morning and 30 minutes in the afternoon. One determination was made on September 9, 1969, at the picking table. The duration of that sampling was one hour. Particle weights were determined by weighing the glass collection plates before and after exposure and by subtracting the two values.

G. ARTHROPOD AND RODENT CONTROL METHODS

The control of arthropod and rodent pests depended both on the application of existing technology and on the development of new technology. Rats and roaches were readily controlled by poison baits and commonly used sprays. The control of flies depended on a study of their habits as they relate to solid waste and compost. A successful fly control procedure was developed on the basis of this study.

The procedures for the control of rodents and roaches were presented as follows:

Rodents: The sealing of the holes around the water pipes entering the washroom reduced the rodent population, so that rats and mice are rarely observed in the Compost Plant. Liquid and dry Pival baits are available for the control of rats, but good housekeeping is the best control.

Roaches: Roaches are normally controlled with a monthly application of a 2.0% Diazinon spray. The best control of roaches is by good housekeeping.

These procedures should interest not only operators of compost plants, but also operators and administrators of solid waste management programs.

The procedures developed for the control of flies are presented in another section of this report. The methods and results are presented together for purposes of continuity.

H. RESULTS

1. Composition of Refuse as Received At the Plant

Knowledge of the composition of refuse received at a compost plant is important to both plant design and operation. It is particularly important in planning salvage operations.

Refuse was analyzed for major constitutents to determine variation within given days, variation between given days, and variation between seasons. Analyses were made on January 24, July 8, August 21, and every day during the period of September 10 - 16, 1970. Samples for the first two dates were taken at the plant receiving platform. The final sample of about 2 yd^3 was comprised of four subsamples taken throughout the day to represent the composition of refuse for those two days. Samples for the remaining analyses were taken at the oscillating conveyor ahead of the picking platform. Refuse located at the last two feet of the output end of the conveyor was collected at designated times throughout the day. This procedure led to unbiased sampling. Samples were sorted by hand into ten major constituents with further subdivision of paper and metal because of their salvage potential. All constituents were weighed and reported as percentages of the total refuse sample on a wet weight basis.

Table 2 shows the composition of refuse received at the plant on August 21, 1969, at designated sample times and the day's average. The data show typical variations throughout the day. Table 2 shows the daily averaged composition of refuse during the period September 10 - 16, 1969, and the weekly average. Table 2 shows a summary of refuse composition on the designated sampling dates. The data collected in September show that there is great variation of each refuse constituent throughout each day. Detailed results representing designated times of each of the 6 sampling days were presented in a previous report(6). There was less variation noted between days. Paper constitutes about 50 percent of the total refuse. Salvageable paper constitutes about 23 percent of the total refuse. Food waste (garbage) averaged about 5 percent, and garden wastes averaged about 13 percent. Ferrous metals comprised 7.5 percent and non-ferrous metals (mainly aluminum) comprised 0.6 percent of the refuse. All data resulting from this study represent waste generation by the local community inasmuch as all the waste, with one exception, is delivered to the

TABLE 2

COMPOSITION OF REFUSE

August 21, 1969

Refuse Category	Percent at Each Sampling Time 8:45	9:45	11:15	1:10	2:30	3:50	Average Percent
Combustible	86.41	86.86	73.17	89.06	78.55	74.41	81.41
Food Waste	1.42	3.47	5.94	5.58	7.93	6.65	5.17
Garden Waste	17.31	1.07	18.19	0	33.14	7.29	12.83
Paper Products	55.70	57.23	25.58	71.61	20.80	38.30	44.87
Salvageable	35.13	33.75	11.85	55.80	6.35	17.49	26.73
Cardboard	16.04	22.81	8.39	55.17	3.31	4.14	18.31
Other	19.09	10.94	3.46	0.63	3.04	13.35	8.42
Nonsalvageable	20.57	23.48	13.73	15.81	14.45	20.81	18.14
Plastic, Leather, Rubber	10.18	5.16	10.76	3.56	5.16	6.85	6.94
Textiles	1.27	0.33	0.34	0.10	6.43	12.39	3.48
Wood, Limbs, Sawdust	0.53	0.29	0.61	8.21	5.09	2.93	2.94
Miscellaneous	0	19.31[1]	11.75[1]	0	0	0	5.18
Noncombustible	13.59	13.14	26.83	10.94	21.45	25.59	18.59
Metal	6.15	7.25	9.46	1.93	8.79	13.03	7.77
Ferrous	5.30	6.63	9.26	1.93	6.27	12.94	7.06
Nonferrous	0.85	0.62	0.20	0	2.52	0.09	0.71
Glass and Ceramic	2.32	3.38	5.21	0.90	3.32	5.35	3.41
Ash, Earth, Rock, Etc.	5.12	2.51	12.16	8.11	9.34	7.21	7.41
Sample Weight in Pounds	30.18	61.40	73.67	50.34	84.01	75.32	374.92

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[1] Wallboard and Tarpaper

TABLE 2

(Continued)

COMPOSITION OF REFUSE

September 10 thru 16, 1969

Refuse Category	Daily Average Percent						Weekly[1] Average Percent
	9-10 Wed	9-11 Thur	9-12 Fri	9-13 Sat	9-15 Mon	9-16 Tue	
Combustible	72.20	78.92	82.13	79.88	85.99	82.52	80.31
Food Waste	2.72	4.55	3.74	13.52	5.59	5.41	5.23
Garden Waste	5.71	11.01	8.51	9.43	22.92	17.04	12.71
Paper Products	50.31	52.96	56.70	50.48	40.13	47.74	49.65
Salvageable	22.23	19.14	32.20	22.05	20.37	25.05	23.64
Cardboard	16.02	15.50	22.96	10.03	8.11	14.62	14.95
Other	6.21	3.64	9.24	12.02	12.26	10.43	8.69
Nonsalvageable	28.08	33.82	24.50	28.43	19.76	22.69	26.01
Plastic, Leather, Rubber	5.60	4.45	6.46	4.17	3.60	3.15	4.61
Textiles	0.88	1.23	0.77	1.65	3.28	1.87	1.61
Wood, Limbs, Sawdust	6.08	4.00	5.95	0.63	10.47	7.31	6.20
Miscellaneous	0.90	0.72	0	0	0	0	0.30
Noncombustible	27.80	21.08	17.87	20.12	14.01	17.48	19.69
Metal	11.64	7.15	6.74	6.74	6.87	8.46	8.04
Ferrous	11.23	6.48	6.44	5.88	6.03	7.83	7.44
Nonferrous	0.41	0.67	0.30	0.86	0.84	0.63	0.60
Glass and Ceramic	6.78	8.71	6.69	10.79	5.30	5.95	7.06
Ash, Earth, Rock, Etc.	9.38	5.22	4.44	2.59	1.84	3.07	4.59
Sample Weight in Pounds	358.45	309.43	416.11	196.17	355.55	390.08	2025.8
Number of Samples	6	6	6	3	6	6	33

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[1] The weekly average percent was calculated by assuming that each of the 33 samples separated were of equal value.

TABLE 2

(Continued)

SUMMARY OF REFUSE COMPOSITION

Refuse Category	Date and Percent (Wet Weight Basis) January 24 Friday	July 8 Tuesday	August 21 Thursday	September 10-16 All Week
Combustible	80.35	84.54	81.41	80.31
Food Waste	5.75	9.29	5.17	5.23
Garden Waste	16.09	4.61	12.83	12.71
Paper Products	53.51	62.33	44.87	49.65
Salvageable[1]	18.66	13.43	26.73	23.64
Cardboard	9.10	-	18.31	14.95
Other	9.56	-	8.42	8.69
Nonsalvageable	34.85	48.90	18.14	26.01
Plastic, Leather, Rubber	2.77	3.19	6.94	4.61
Textiles	2.10	3.58	3.48	1.61
Wood, Limbs, Sawdust	0.13	1.54	2.94	6.20
Miscellaneous	0	0	5.18	0.30
Noncombustible	19.65	15.46	18.59	19.69
Metal	7.55	6.68	7.77	8.04
Ferrous	6.98	5.50	7.06	7.44
Nonferrous	0.57	1.18	0.71	0.60
Glass and Ceramic	6.54	5.38	3.41	7.06
Ash, Earth, Rock, Etc.	5.56	3.40	7.41	4.59
Sample Weight in Pounds	328.	231.	375.	2026.
Number of Separations	1	1	6	33

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[1] As used here, the term salvageable paper refers to those pieces of paper which are large enough, dry enough, and clean enough to be separated at the sorting platform for subsequent sale.

compost plant. Demolition wastes and bulky wastes such as automobiles and appliances were taken directly to landfills.

2. Composition of Material Removed by Magnets

The composition of the material removed by the magnets is important information for use in metal salvage considerations. At the time of this study (March 19, 1969) two electromagnets were used to remove ferrous metals. They are located after the secondary grinder and after the digesters. A sample of the material removed by each magnet was collected, weighed, dried, and burned to determine its composition. The compost leaving the final grinder was also examined for the amount of metal present.

The samples taken at the magnets were burned with an acetylene torch to approximate conditions in a metal salvage incinerator and to simulate metal which would meet market requirements. The metal and ash were then separated and weighed. The following compilation shows the composition of material removed by the magnets:

Magnet Location	Composition of Material, % of Total				Sample Size lbs.
	Moisture	Volatile Solids	Metal	Ash	
After Secondary Grinder	3.8	6.6	88.5	1.1	10.4
After Digesters	8.7	13.5	68.2	9.6	3.9

A sample of final grind compost (5.7 lbs.) was spread out on a flat surface and a hand magnet was used to take out the small amount of remaining ferrous metal. The nonferrous metal (mainly aluminum) was removed by hand picking. The sample contained 43.8 percent moisture, 0.14 percent ferrous metal, and 0.06 percent nonferrous metal. These results show that the two magnets are removing almost all of the ferrous metal and that the first magnet is removing cleaner metal than the second one. The indication is that the material taken at the magnet after the secondary grinder has definite salvage potential if a profitable market can be found.

3. Bulk Density of Refuse as Placed in Digester

The bulk density of the refuse as placed in the digester is a valuable parameter which may be used to determine digester size and to design refuse handling equipment.

Records were kept for a three day period beginning Monday, March 10, 1969, of the refuse received, paper salvaged, non-compostables removed at the sorting platform, material removed by the magnet after the secondary grinder, and compostables to the digester:

ITEM	TONS	PERCENT
Refuse Received	481.5	100.00
Paper Salvaged	40.5	8.41
Non-Compostables Removed	102.5	21.29
At Sorting Platform	(74.9)	(15.56)
At Magnets	(27.6)	(5.73)
Compostables to Digester	338.5	70.30

At the time the records were made, water was being added at the secondary grinder in lieu of sewage sludge. The amount of water added was 740 gallons per hour. The estimated total amount of water added was based on the number of hours (19.4) that the conveyor belt operated. The amount of water added over the three day period was, therefore, estimated to be 59.8 tons.

The dimensions of ground refuse mass in the digester were 20.0 ft. x 7.16 ft. x 223.5 ft. The volume was 1185 cubic yards.

The moisture content of a grab sample of the material as placed was 44 percent. The total weight of the refuse plus water placed in the digester was 398.3 tons.

The resulting bulk density is only an approximation because of the difficulty of determining the amount of water added and of measuring the height of the uneven surface of the refuse in the digester. An error analysis made of the data indicates that the bulk density value is 670 ± 60 lb/yd^3.

4. Moisture Content of Refuse and Compost

Refuse moisture contents were determined periodically at several points in the composting process. This information is useful for process control and for research.

Moisture analyses were made on samples of refuse just before secondary grinding on refuse as placed in the digesters, and on compost immediately after final grinding. Data derived from the first sampling point gave an excellent estimate of the moisture content of refuse as it is received at the plant and hence the amount of sewage sludge that may be added. Some error was introduced by the prior separation of the noncompostable fraction. However, grinding prior to sampling greatly enhances the homogeneity of the sample resulting in reasonably precise determinations.

Samples of about 500 g were collected for the determination of moisture in refuse just prior to secondary grinding. Samples of refuse and compost from other sources usually ranged from 10 - 100 g. All samples were dried at 75°C to constant weight. Normally two days were required to dry the sample. Table 3 shows a summary of all moisture analyses made during the period of May - October, 1969. Moisture contents are reported as a percent of the wet weight. The increased moisture of the refuse as placed in the digester in October is a result of more sewage sludge addition.

Data for three months has been gathered on moisture content of the refuse samples taken before the secondary grinder. Rainfall data were compared with refuse moisture data. The following compilation shows the effect of rainfall on the moisture content and weight of refuse received at the plant.

Month - 1969	Total Tons	% Moisture	Tons Liquid	Tons Solid	Rainfall Inches
August	3376	28.5	960	2416	9.5
September	4068	30.0	1219	2849	11.5
October	3718	23.6	877	2841	1.2

TABLE 3

REFUSE MOISTURE CONTENT

MOISTURE CONTENT AS PERCENT OF WET WEIGHT

	Before Secondary Grinder				As Placed In Digester				After Final Grinder			
1969 Month	Average	Range	Standard Deviation	No. of Samples	Average	Range	Standard Deviation	No. of Samples	Average	Range	Standard Deviation	No. of Samples
May	-	-	-	-	48.8	19-75	12.5	23	44.6	37-61	7.1	9
June	-	-	-	-	38.0	22-46	13.9	3	39.9	34-47	4.5	9
July	-	-	-	-	48.3	35-74	7.0	26	40.9	24-54	8.4	10
August	28.5	16-39	6.9	9	44.3	23-60	8.8	18	38.8	32-54	6.9	9
September	30.0	17-50	11.0	10	45.8	26-72	10.8	46	43.5	35-48	9.0	3
October	23.6	17-29	4.1	11	55.0	30-77	11.9	81	54.6	-	-	1

The refuse total for October was adjusted upward 220 tons from the actual 3498 tons received to correct for two days when the plant was not operated. August was a low tonnage month mainly because of the decrease in enrollment at the University. In September, the students returned and a record 4068 tons of refuse was processed. Even after adjusting the tonnage for October, the refuse for the month is about 350 tons less than that for September. The data show that the difference between the total refuse weights for September and October is mainly due to the difference in moisture contents. The refuse solids calculated for the two months agreed quite closely. These data indicate that the actual refuse production for the months of September and October was about the same, even though the wet weights alone showed considerable difference. This difference was attributable to rainfall. A plot (not shown) of percent moisture of the compostable refuse versus inches of rain per month for the three months of data collected to date indicates a linear relationship.

5. Sewage Sludge Utilization

The treatment of raw sewage sludge in conjunction with composting refuse would be highly desirable in that it has the potential for greatly reducing waste treatment costs.

The digestion of sewage sludge by conventional processes is costly and inefficient. The cost of sludge treatment and disposal by conventional means approaches 50 percent of the total cost of treating sewage. By contrast, the treatment of sewage sludge by composting along with refuse adds very little to the cost of refuse composting. Also, sludge contains nutrients, particularly nitrogen, which might enhance waste decomposition and enrich the compost product. Finally, the refuse as it is received contains insufficient moisture for good decomposition to occur. This necessitates adding water. Sludge might replace water for this purpose.

Digested sewage sludge has been treated intermittently at the Gainesville compost plant during the period from June, 1968 to April, 1969. During that time the feasibility of composting refuse-sludge mixtures was shown. The sludge supplement did not hinder refuse decomposition. It did reduce the numbers of coliform bacteria which survived the composting process. Tests over an extended period of time indicated that the probability of survival of pathogens during digestion was very low.

Up to April, 1969, sludge had merely been disposed of by composting after it had been digested at the sewage treatment plant. The feasibility and safety of treating raw sewage sludge had been indicated. Therefore, the treatment of raw sludge by composting was initiated on April 28, 1969. Ideally, the compost plant should have the capability for treating the entire quantity of sludge and solid waste produced by a given population. This would eliminate the need for sludge digestion at the sewage treatment plant. The resulting savings would offset operating costs at the compost plant.

Several problems had to be solved before this goal could be achieved. The first raw sludge to be treated had a solids content of only 1.5% (98.5% water). It would not be possible to consume all of the city's sludge if its moisture content were that high. The result would be a refuse-sludge blend far too wet to handle and compost by the existing process. Table 4 shows that because of this restriction only 10% of the total raw sludge produced by the City was treated by composting during May, 1969.

Another obstacle to sludge addition was the narrow conveyor belt on the tripper which is used to place ground refuse in the digester. The conveyor would bind occasionally and stop when the refuse moisture content approached 60%. This stopped the entire operation of the plant. A wider conveyor belt was installed on October 4, 1969, and there has been no more difficulty.

A two inch plastic pipe was installed to carry sludge from the sludge reservoir to the mixing screws. This proved to be undependable because of periodic breaks in the pipe and separation of the pipe joints. To insure a more dependable system, the plastic pipe was replaced by a four inch galvanized steel pipe on October 20.

The City installed a six inch cast iron pipeline to carry sludge from the sewage treatment plant to the sludge reservoir at the compost plant. The new pipeline was first used on October 21, and it has worked well since then. Prior to that date, sludge was trucked to the compost plant.

TABLE 4

SEWAGE SLUDGE UTILIZATION
Gainesville Compost Plant

	Sewage Treatment Plant				Compost Plant		
		Sewage Sludge					
			To Compost Plant				
	Raw[1] Sewage Flow	Total[1] Withdrawn	Thousand	Percent[6]	Total Refuse Received	Compostables To Digester	Ratio of Sewage Sludge to Compostable Refuse
Month	MG	MG	Gallons	of Total	Tons	Tons	Gallons per Ton
Jan. '68	139.9	0.600	0	0	134.0	106.8	0
Feb.	133.4	0.510	0	0	277.9	243.7	0
March	147.8	0.489	0	0	461.1	401.2	0
April	147.8	0.512	0	0	974.1	795.3	0
May	142.6	0.575	0	0	2448.4	2052.8	0
June	178.5	0.532	189.2[2]	(35.6)	2450.4	1909.5	99.0
July	205.1	0.568	0	0	1478.2	1247.5	0
Aug.	239.5	0.528	0	0	293.0	260.9	0
Sept.	260.8	0.731	0	0	2360.5	1844.3	0
Oct.	216.3	0.752	102.8	(13.6)	2533.7	1832.1	56.0
Nov.	191.5	0.742	10.8	(1.4)	2312.9	1664.9	6.5
Dec.	173.0	0.576	81.0	(14.0)	2526.3	1748.6	46.4
Jan. '69	179.1	0.725	81.0	(11.2)	2972.4	2084.9	38.8
Feb.	172.7	0.726	55.8	(7.7)	2723.2	1887.8	29.6
March	202.8	0.904	0	0	2917.6	2161.5	0
April	181.7	0.980	18.9[3]	(1.9)	1317.6	759.9	24.9
May	177.3	1.379	143.9	10.4	2042.0	1407.6	102.0
June	178.7	1.330	5.4	0.4	1023.1	730.2	7.4
July	210.1	1.247[4]	54.9	4.4	3239.9	2506.8	21.9
August	209.9	1.275	133.6	10.5	3376.1	2604.8	51.5
Sept.	230.7	1.309	108.1	8.3	4067.7	3324.0	32.6
Oct.	241.7	1.099	240.9[5]	47.5[7]	3498.4	2833.9	85.0
Nov.	187.3	0.798	241.7	(30.3)	3003.4	2369.8	101.9
Dec.	206.9	0.750	321.7	(42.9)	3891.1	3193.9	100.7

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[1] From records at sewage treatment plant. (MG = million gallons)

[2] Digested sewage sludge addition begun June 5, 1968.

[3] Raw sewage sludge addition begun April 28, 1969.

[4] Sewage sludge solids found to be 1.25 percent.

[5] Thicker sludge addition begun Oct. 15, 1969.

[6] The results enclosed by parenthesis are only the apparent percent treated. No allowance was made for the effect of sludge thickening because of insufficient data.

[7] Estimated on the basis of sludge solids results.

A Moyno pump is used to transfer sludge from the sludge reservoir to the mixing screws. It is the only means for controlling the ratio of sludge to refuse. It is not practical to adjust the flow of refuse for this purpose. Although the pump speed can be varied, a convenient means to keep the sludge-refuse ratio constant by varying the pump speed has not been developed. Consequently, the only existing means for controlling this ratio is to turn the pump on or off. This is only marginally satisfactory and a better means for regulating the sludge-refuse ratio is urgently needed.

Attempts are being made to compost the entire output of sludge from the City. Starting on October 15, 1969, a thick sludge having a solids content ranging from 5 - 8% has been received. The thick sludge was obtained by withdrawing it from the bottom of the sewage plant digesters after it had settled. Using sludge of this thickness, it should be possible to compost the entire sludge output of the sewage treatment plant. The system existing at the termination of the project was somewhat expedient. A digester was used to thicken sludge by settling. During this process the sludge was partially treated. This was a temporary measure pending the completion of construction at the sewage treatment plant. Nevertheless, it now appears feasible to compost the entire sludge output from the City.

The addition to the sewage treatment plant recently has been completed. The existing plant (trickling filter) has a design capacity of 5.0 MGD. The addition (contact stabilization) has an additional design capacity of 4.5 MGD. The addition to the sewage treatment plant does not include sludge digestion tanks because it is expected that the compost plant will have the capability for treating the majority of the sludge produced. A 30 foot diameter picket type sludge thickener is included in the sewage treatment plant addition and is expected to dewater sludge to a solids content of 4 to 6 percent.

Records maintained by sewage treatment plant personnel show that during the period of May through September, 1969, about 1.33 million gallons of raw sludge were withdrawn each month. The contributing population was about 52,000. Sludge solids analyses of raw sludge delivered to the compost plant have averaged about 1.5%. Based on these figures, the sludge solids production of the City appears to be about 85 tons per month.

The compost plant is currently used for treating all the refuse from the City, University, and County near the City. The contributing population is estimated as follows:

City of Gainesville	=	52,000
University of Florida	=	11,100
Alachua County (near City)	=	6,400
Total		69,500

The average amount of refuse received was 3500 tons per month based on data for July through December. The October receipts have been adjusted to allow for a few days when plant modifications were being made and no refuse could be accepted. An estimate of the degree of sludge thickening required if all of the City's sludge is to be composted can be made on the basis of typical amounts of refuse and sewage sludge produced and their moisture contents. The following theoretical compilation is based on raw sewage sludge production of 1.33 MG per month at a solids content of 1.5% and refuse production of 3500 tons per month with 3000 tons per month of compostables at 30% moisture.

SLUDGE SOLIDS REQUIRED TO COMPOST ALL SLUDGE

Sewage Sludge		Sludge Plus Refuse	Ratio of Sludge To Compostable Refuse
% Solids	Total Thousand Gallons Per Month	% Moisture	Gal/Ton
4	500	57.2	167
5	402	53.5	134
6	334	50.5	111
7	286	48.2	96
8	250	46.2	84

This estimate shows that 134 gallons of sludge per ton of compostable refuse would be required to dispose of all the sludge, provided the solids content is 5%. Thicker sludge would require less volume and may be necessary during period of heavy rainfall. The two digesters at the sewage treatment plant (0.5 MG each) could serve as additional sludge storage reservoirs during periods when the refuse is wet.

An estimate of the sewage sludge treated at the compost plant during October, 1968, was made based on records of volume and percent solids:

Amount of Sludge Composted During October, 1969

Period	Gallons	Tons	% Solids	Tons Solids
1st to 14th	102,780	435	1.5	6.5
15th to 31st	138,080	586	5.8	34.0
WHOLE MONTH	240,860			40.5

The 40.5 tons of sludge solids estimated amounts of 47.5% of the 85 tons produced by the City each month. The calculations show that most of the sludge was treated during the last half of the month when thicker sludge was being treated. An estimated 100,000 gallons of water was added in place of sewage sludge during October because of sludge handling modifications. The combined amount of sludge and water used for the month was, therefore, 340,000 gallons.

Data from the period in October when thick sludge was added indicate that the compost plant can take all the sludge from the City. During the week of October 27 through 31, a total of

73,000 gallons of thick sludge (about 6 to 8% solids) was mixed with 610 tons of compostable refuse resulting in a sludge-refuse ratio of 120 gallons per ton. These results and the previous theoretical calculations indicate that a strong potential exists for consuming all of the sludge produced by the City.

6. Effect of Sewage Sludge on Refuse Decomposition

The incorporation of raw sewage sludge into composting refuse may be a successful method for sludge disposal. Additionally, the cost of this type of sludge disposal is expected to be very low as compared with conventional methods. Thus, the cost of composting might be credited with the savings realized by this type of combined treatment.

This important aspect of composting was studied to determine its technical and economic feasibility. The use of digested sewage sludge as the moistening agent for ground refuse was initiated on June 5, 1968. City water had been used prior to that date. When experience from plant operation showed that sludge could be used and laboratory studies showed high probability for pathogen destruction raw sewage sludge was used for moistening. This practice was started on April 28, 1969. This presented an opportunity to compare the effect of the two moistening agents on refuse decomposition. This was done by comparing C/N ratio reduction of water-moistened refuse with that of sludge-moistened refuse. Table 5 suggests that the reduction of

TABLE 5

EFFECT OF SLUDGE

EXPERIMENT 2

Sample Description	C,%	N,%	C/N Ratio	BOD, mg/g	COD, mg/g	Volatile Solids, %	pH
Raw Refuse + 1/2 1 sludge	36.2	.600	60.4	98.8	7330	66.7	6.25
Digested Refuse + 1/2 1 sludge	34.0	.526	64.7	73.2	10810	66.9	6.1
Raw Refuse + 1 1 sludge	37.5	.602	62.2	36.6	8500	71.7	6.35
Digested Refuse + 1 1 sludge	39.3	.539	73.0	65.4	11830	69.5	5.65

C/N ratio was approximately 60 percent greater when sludge had been used as compared with water. However, this difference is not convincingly significant because of the limited analytical precision. This work was based on the analysis of compost samples which did not necessarily represent comparable samples of raw refuse. After the development of the Fiberglas bag technique, the same sample could be analyzed before and after composting.

Experiments were designed to determine the effect of sewage sludge on the decomposition of refuse and on the quality of the compost product. Raw refuse and compost was analyzed for carbon, nitrogen (hence the C/N ratio), COD, BOD, and volatile solids. A greater reduction of C/N ratio and the other three parameters manifested by the sludge amended compost than in the unamended compost was evidence that sludge enchanced the composting process. In each experiment a quantity (usually 1/4 - 1/2 yd^3) of raw ground refuse was mixed with a shovel or fork. A sample of this refuse was analyzed. Other samples were put into Fiberglas bags which were placed in the digester within the production quantity of refuse. Sewage sludge in varying quantities and concentrations was added to still other samples. These were analyzed before and after composting.

A total of 8 experiments incorporating 44 treatments and replications were made to determine the effects of sludge supplements on refuse composting. Detailed results were reported previously(5,6).

Analyses for C/N ratio, COD, BOD, and volatile solids were never consistent in showing that sludge stimulated waste decomposition. The BOD test was the most reliable for this purpose, whereas the volatile solids test was least reliable. There were no indications from these four tests that sludge could not be treated by composting. Some experiments showed that high concentrations of sludge added significant quantities of putrescible matter to raw waste. Furthermore, putrescible matter in the sludge supplemented compost was frequently higher than that in the unsupplemented compost indicating that sludge burdened the composting process. The highest concentration of sludge which was evaluated was 0.64 kg sludge (2.3 percent solids) per kg of refuse, which is equivalent to 154 gallons per ton. Even at this high concentration of sludge there were no indications that the process was seriously hindered.

Sewage sludge also has the potential for enriching the compost product with nutritional elements. Nitrogen is the most important element which might be added by sludge supplements. The addition of sludge did, in fact, raise the nitrogen content of the refuse-sludge mixture. The nitrogen content of unsupplemented refuse typically ranged rom 0.4 - 0.7 percent; that of supplemented refuse typically ranged from 0.4 - 1.1 percent. There is evidence that nitrogen was lost during the composting of sludge supplemented refuse. It can be expected that nitrogen in the form of ammonium compounds would be lost during the thermophilic stage of composting. The mechanism of this loss was not studied, but analysis of refuse heavily supplemented with sludge before and after composting frequently showed a loss of nitrogen ranging from 0.1 - 0.3 percent.

The addition of sewage sludge to refuse had an unexpected effect on the coliform populations in the composting refuse. Table (Section H-12) shows that when water was used to moisten raw ground refuse the coliform population in the resulting compost remained stationary or increased relative to the original population. By contrast, when sewage sludge was used the coliform population in the resulting compost decreased except possibly during the sampling period of October 2, through December 31, 1968. Because the usual standard deviation of the MPN method for the determination of coliform indices is no better than one logarithmic unit, even this apparent increase may not be real. The extent of coliform reduction when sludge was added can be equated approximately to the amount of sludge being added. For example, during the June 5 - June 26, 1968, sampling period when sludge was added at the rate of 77.2 gal per ton of refuse, the coliform population was reduced by four logarithmic units. During January and February of 1969, when sludge was added for the most part at the rate of 27.2 gal per ton of refuse, the coliform population was reduced by only two logarithmic units. In the conduct of this work there was no assurance that the same refuse was assayed before and after composting. Thus, the data can be expected to vary widely. In spite of this, the large number of assays made strongly suggests that sludge supplements do indeed reduce coliform numbers.

Compost derived from sludge supplemented refuse was darker than that derived from water moistened refuse. The difference in color usually was subtile and, therefore, was not noticeable until the compost had been finely ground for chemical analysis. Color observations were made on matched samples prepared for composting in the Fiberglas bags. Untreated control samples, including those which received sludge and composted controls which were moistened with water, were light grey and were indistinguishable on the basis of color. When sludge was added at varying quantities the darkness of color in the compost was directly related to the quantity of sludge added to the refuse. Thus, the dark color resulted from the composting of sludge-supplemented waste and not from the sludge itself. In the 7 of 8 experiments designed to determine the effects of sludge on composting by the Fiberglas bag method of sampling, there were color differences among the samples which were attributable to sludge. Experience in the practice of composting indicates that as compost becomes progressively stabilized it becomes darker.

Still another effect of sludge on composting was noted. Limited data suggest that there is a greater loss of weight resulting from the composting of sludge supplemented refuse than from composting water moistened refuse. In some early work ground refuse in Fiberglas bags was weighed before and after composting to determine weight losses. Weight losses of water moistened and sludge moistened compost were determined in separate experiments according to how the production refuse was moistened. Experimental variation was so great that no conclusions could be drawn. In subsequent work weight losses of closely matched samples were compared. In the only experiment when this was done, water moistened refuse lost 2.8 percent weight as a result of digestion for 6 days and windrow curing for 30 days. Sludge moistened refuse which received identical treatment lost 9.3 percent weight. It must be emphasized that although this experiment was carefully controlled, the resulting data are only single determinations.

Sludge as contrasted with water as the moistening agent caused several other pronounced effects on the digestion of refuse as follows: 1) temperatures rose more rapidly, 2) temperatures were more uniform throughout the digester, and 3) oxygen consumption was much greater. These results were presented in detail in a previous report(6). In review, however, when sludge was used for moistening, the temperatures in the digesters leveled off between the second and fourth days. When no sludge was used temperatures did not level off until the fifth or sixth days. Uniformity of temperatures at the various levels in the digester was demonstrated by the narrow range of 162-172°F on the third day sludge was added. Typically, temperatures ranged from 140-165°F on the third day when no sludge was added. These ranges do not include temperatures at the bottom 6 inches of the digester which typically are approximately 100°F, regardless of whether water or sludge had been added. The high oxygen demand of sludge was also manifested. When no sludge was added the typical oxygen residual in the digesters ranged from 16 - 19 percent. When thick sludge was added this residual concentration was about 9 percent even though the aeration period was extended from 16 to 28 minutes per hour.

In conclusion, there was no experimental evidence to show that raw sewage sludge could not be used as a moistening agent for refuse which is to be composted. It will be necessary, however, to furnish additional air to the digesters when large amounts of sludge are added. An operational problem which is correctable was occasionally experienced in the plant. If the plant operator becomes careless and fails to turn off the sludge pump when no refuse is being processed sludge is spilled about the plant. This gives rise to various public health problems such as odors and flies. The same carelessness when water is being used leads to no serious problems. It was not conclusively demonstrated that sewage sludge enhanced or stimulated the decomposition of refuse. However, evidence from a wide variety of experiments and observations suggests that there was some stimulation as well as enhanced killing of coliform bacteria.

It is doubtful whether the stimulation of refuse decomposition can be substantiated on an industrial scale. Attaining the necessary controls would be impractical if not impossible. Controlled laboratory work would be more definite and efficient.

7. Decomposition of Refuse in the Digester

The scope of this investigation was centered around characterizing refuse decomposition in the digesters. The objective was to optimize the digestion process. In the operation of the plant process variables such as detention time and aeration rates were selected arbitrarily, for the most part. Therefore, it is likely that they could be improved. The effects of process variables on digestion were determined on the basis of heat production (measured as temperatures), CO_2 concentration and oxygen concentration.

A series of two experiments was designed to show the effect of refuse particle size on the rate of decomposition. A series of 6 experiments was designed to show the effects of adding sewage sludge and of aerating the refuse at four different rates. The first two experiments, one of which sludge was used and the other without sludge, were somewhat preliminary. The other four experiments, in which the aeration rates were tested, were more conclusive. One of the aeration experiments also provided valuable information on sludge digestion.

a) Decomposition Rate as A Function of Particle Size: The rate of decomposition was compared in both coursely and finely ground refuse. Rates were judged on the basis of temperature development in the digesters. Finely ground refuse was obtained by shredding it with both the primary and secondary grinders. Coursely ground refuse was obtained by shredding it with only the secondary grinder. Water was used to moisten both types of refuse. Temperatures of the finely ground refuse rose from 120°F to values ranging from 167°F to 183°F after six days of digestion. Temperatures of the coursely ground refuse rose from about 115°F to the range of 153°F to 164°F after six days. Thus, it was indicated that finely ground refuse decomposed in the digesters at a considerably higher rate. However, other factors such as moisture content, refuse composition, and air supply may have influenced the results. The opportunity to use the combination of grinders never occurred again, and these important experiments were not repeated.

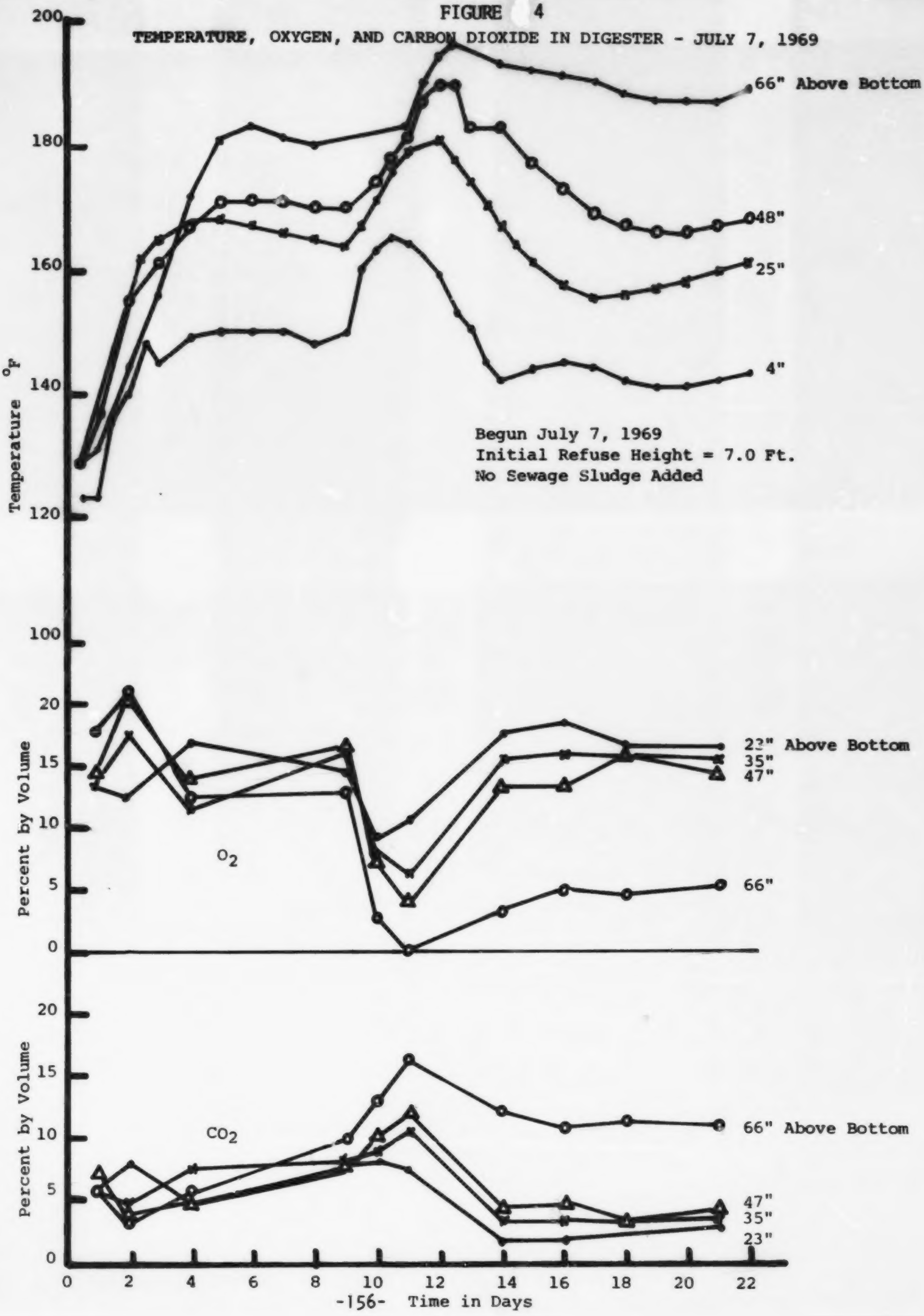
b) No Sewage Sludge - July 7: The refuse under test was among the first to be ground with the new primary grinder. The particle size of the material as placed in the digester was quite small compared with that of previous operations. The test area was located at the north end of the east digester. Water addition resulted in an initial moisture content of about 50%. The refuse was held in the digester for 22 days for the experiment. A Hays Model 621.31:30 Orsat gas analyzer was used for the determination of oxygen and carbon dioxide. The Minneapolis-Honeywell instrument console was unreliable for gas analyses, but it was satisfactorily used for the determination and recording of temperatures. These instruments were used in this entire series of experiments. In the normal operation of the digesters, the aeration blowers run intermittently. This causes considerable fluctuation in digester gas content. To minimize these fluctuations, the gas analyses were made just before the blower turned on.

Figure 4 shows that the temperature and CO_2 curves paralleled each other fairly well whereas the oxygen curve opposed the other two. This was as expected because heat and CO_2 are products of decomposition and oxygen is a reactant. Note that the elevations at which the temperatures were taken do not necessarily correspond with the elevations at which gas samples were taken. However, three of the four curves correspond very closely.

About 4 - 5 days were required before temperatures leveled off. From 0 - 2 days, temperatures at all levels were within 15°F of each other; after that time they diverged rapidly. In the beginning, temperatures at the 25 in. and 48 in. levels were higher than that at the 66 in. level. Between the third and fourth days, the temperatures at these levels reversed and after then they were invariably cooler with increasing depth. This indicates the decomposition started sooner

FIGURE 4

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - JULY 7, 1969



Begun July 7, 1969
Initial Refuse Height = 7.0 Ft.
No Sewage Sludge Added

near the bottom of the digester than at the top. Oxygen consumption and CO_2 production tended to verify this. Subsequently, heat was transferred upwards.

The digesters are forcibly aerated and it is possible and desirable to keep the oxygen content at a uniformly high level. However, somewhere between days 9 and 10 the oxygen content of the gas in the refuse dropped. This happened when refuse was removed from an area in the digester adjacent to the test area. This allowed the air to pass freely through the empty digester rather than through the test waste. On day 11, the air duct valves were closed where there was no waste and the oxygen level in the test area began to increase to previous values. The temperature rose from a maximum of 183°F at 11 days to 196°F at 12.5 days due to the large increase in air supply. On or about day 19, some more waste was removed near the test area. This caused temperatures to rise again.

This experiment strongly suggests that it would be desirable to agitate the waste during its digestion. Agitation would tend to equalize temperatures and concentrations of oxygen and carbon dioxide. A logical first time to agitate may be at four days, or the first time that temperatures at various levels begin to differ widely. That aeration had a cooling effect was shown by the rapidly rising temperatures at all levels when the aeration rate was reduced.

Oxygen and CO_2 concentrations were determined frequently for a period of two hours to determine their ranges as a function of the aeration cycle. Knowledge of these ranges is useful in interpreting Figures 4-11, which consist of data taken just prior to turning on the blowers. Determinations were made at the 5.5 ft. level. Gas concentrations were determined only in the north half of the east digester. One blower serves both the north and south digester halves. The aeration period was 18 min/hr. for the north half and 20 min/hr. for the south half. Figure 5 shows that the oxygen ranged from 3% to 9% by volume during the aeration cycle. Carbon dioxide levels ranged from 8% to 13%. The gas composition data show that some air was going to the north half while the south half was being aerated. This was evidently the result of one of the air duct valves not being completely closed. The additional air to the north half resulted in less variation in the gas composition than would be expected under normal conditions. The results also show that the refuse in the digester still has a significant oxygen demand after 21 days.

Figure 6 shows the moisture content at 10, 15, and 22 days in the digester. Samples were inspected for physical appearance on the twenty-second day of test. Those taken from the upper third of the digester appeared more decomposed than any other samples. This is the region of highest temperature during most of the detention period and the lowest moisture content near the end of detention. The available data neither support nor discount a possible correlation between these two conditions.

FIGURE 5

OXYGEN AND CARBON DIOXIDE LEVELS IN DIGESTER - JULY 28, 1969
Readings Made at 5.5 Ft. Elevation after 21 Days in Digester

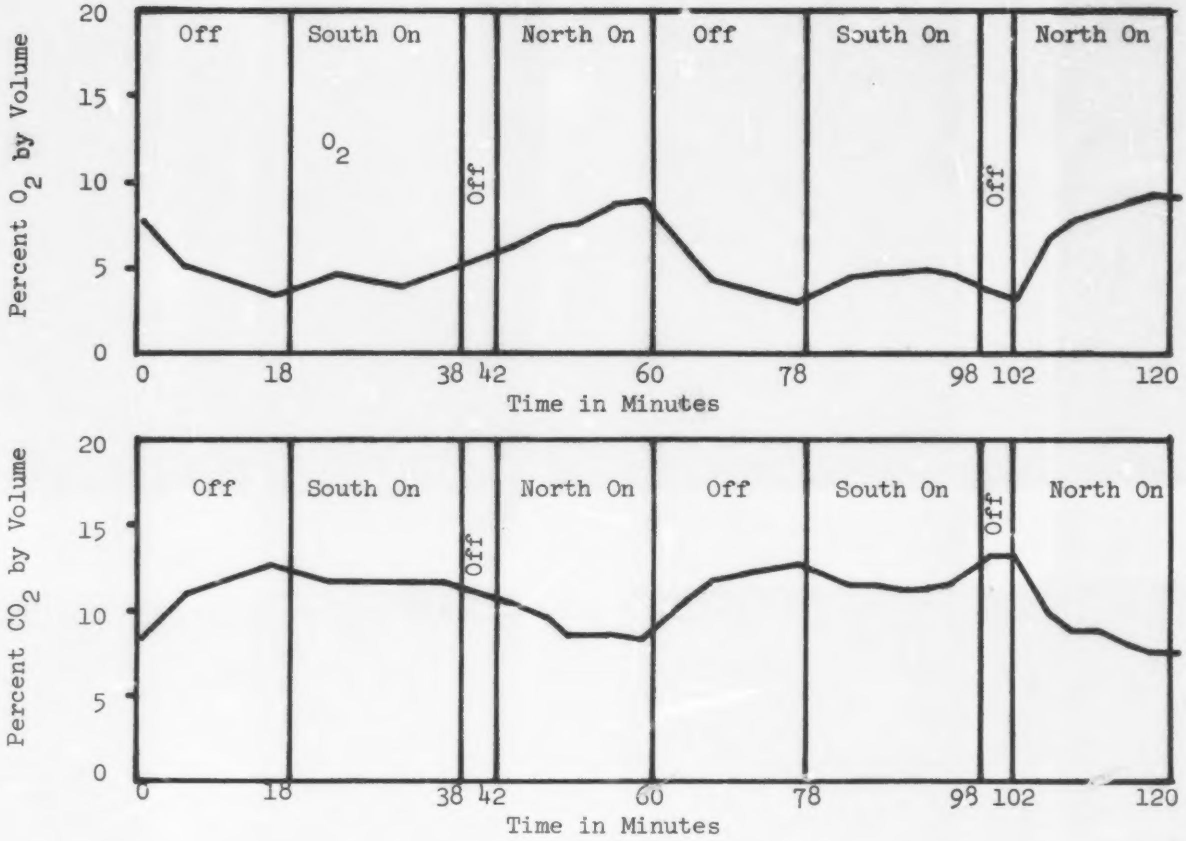
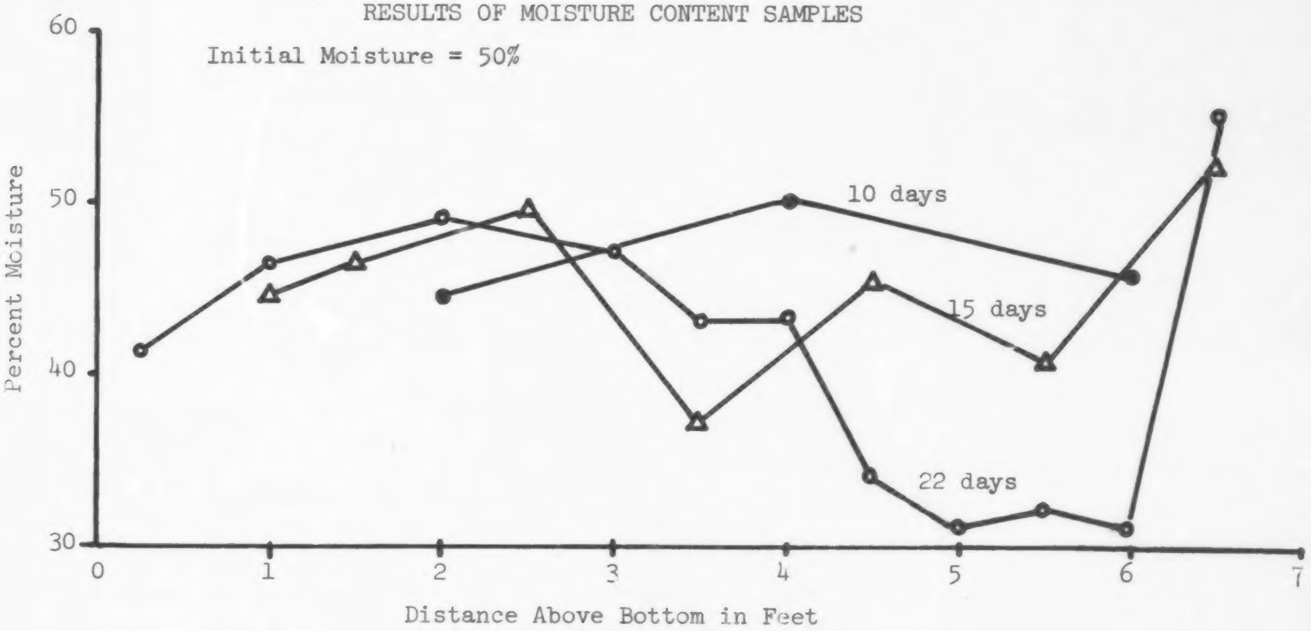


FIGURE 6

RESULTS OF MOISTURE CONTENT SAMPLES



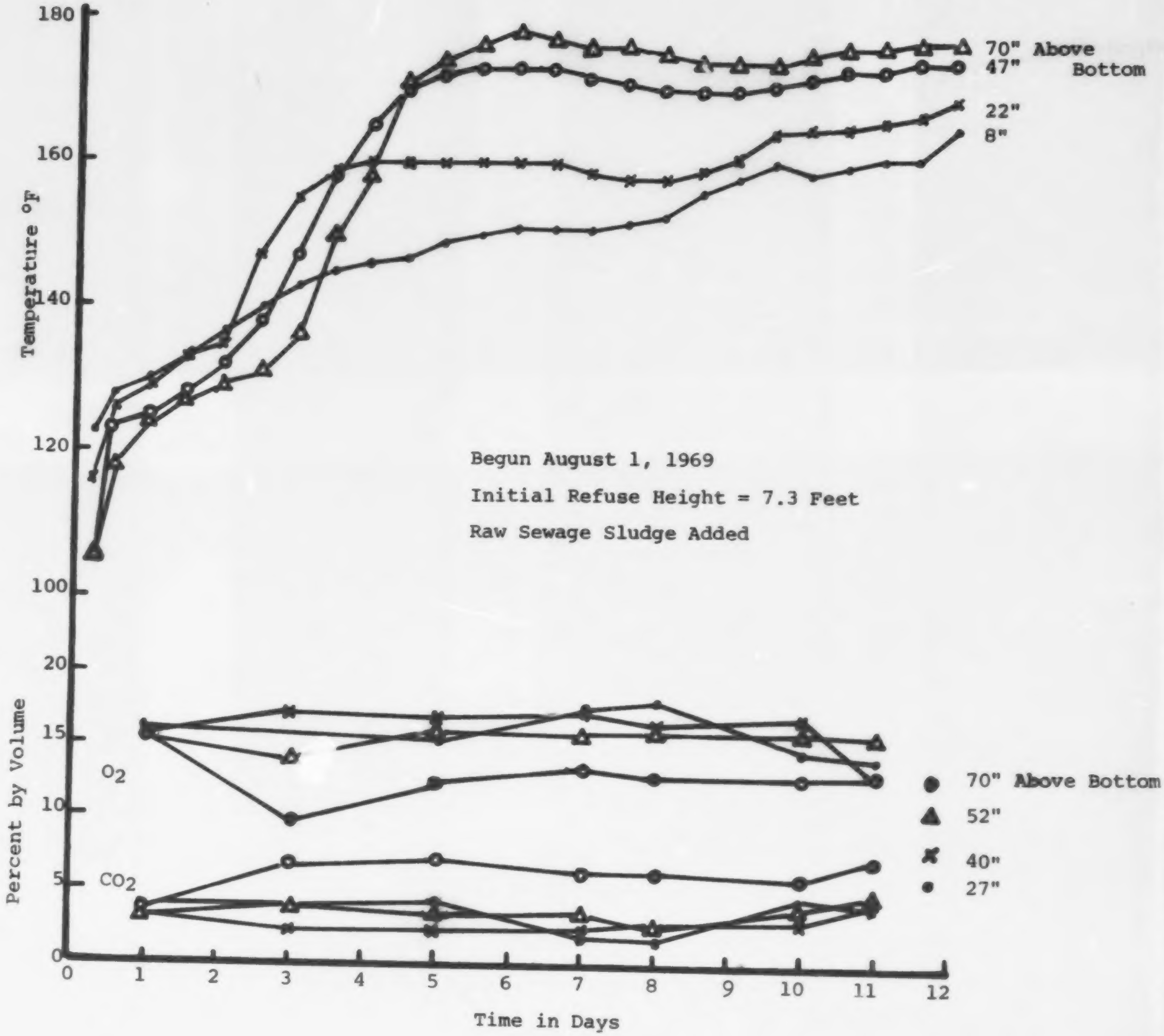
c) Raw sewage sludge - August 1: This is the first experiment in which raw sewage sludge was used as the moistening agent. The test area was at the north end of the east digester. The quantity of sludge added was approximately 50 gallons per ton of refuse moistened. Sludge solids were estimated to be 1.5 percent. The initial moisture was 43%. Air volumes were determined by the air flow meter on the instrument console. Air was regulated by the digester duct valves to approximately 4.5 ft^3 per hour per ft^3 of refuse.

The moisture in the upper third of the digester at 7 days ranged from 43% to 57%. Figure 7 shows that the temperature rose at about the same rate as in the previous experiment when no sludge was added. Maximum temperatures achieved were about the same prior to the disturbance experienced during the first test. Apparently the quantity of sludge added was too small to produce a noticeable effect.

The compost was removed from the digester after twelve (12) days and the moisture content and pH at various elevations measured:

Elevation in Inches	% Moisture	pH
87	28.1	6.5
75	43.8	4.8
63	44.7	5.1
51	49.1	4.9
39	52.0	5.1
27	43.7	5.2
15	38.8	6.0
3	23.2	6.9

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - AUG. 1, 1969



Begun August 1, 1969

Initial Refuse Height = 7.3 Feet

Raw Sewage Sludge Added

FIGURE 7

These data further suggest that decomposition is not uniform in the digester and that there is a need for periodically mixing the refuse. Moisture contents of waste near the top and bottom of the digester were below the generally recognized range for good composting (40 - 65%). It should be noted that generally the pH varied inversely with moisture content.

d) Effect of Aeration Rate - August 20, September 4 and 16:

The effect of aeration rate on the composting process was studied by varying the air supply and observing the temperature and gas results during the usual 8 day digester detention time. The study was made in the north half of the west digester. The first step was to determine the output of the aeration blower with the digester full of refuse. The air flow meter of the instrument console was used as the basis for regulating the valves on the air supply ducts to obtain a uniform air supply along the digester. The air supply was about 3800 cubic feet per minute (cfm) for the north digester half or about 540 cfm for each of the seven 20.67 feet long tanks. At the time the study was made, the blower ran 16 minutes per hour on the north half of the digester.

The third experiment was started on August 20 with an almost normal air supply of 600 cfm per tank. The initial refuse height was 6.7 feet. Therefore, the resulting aeration rate was 3.52 ft^3 per hour per ft^3 refuse. Raw sewage sludge was added to give an initial moisture content of 49%. Samples taken from an elevation of five feet at 3 and 8 days contained 44% and 43% moisture, respectively.

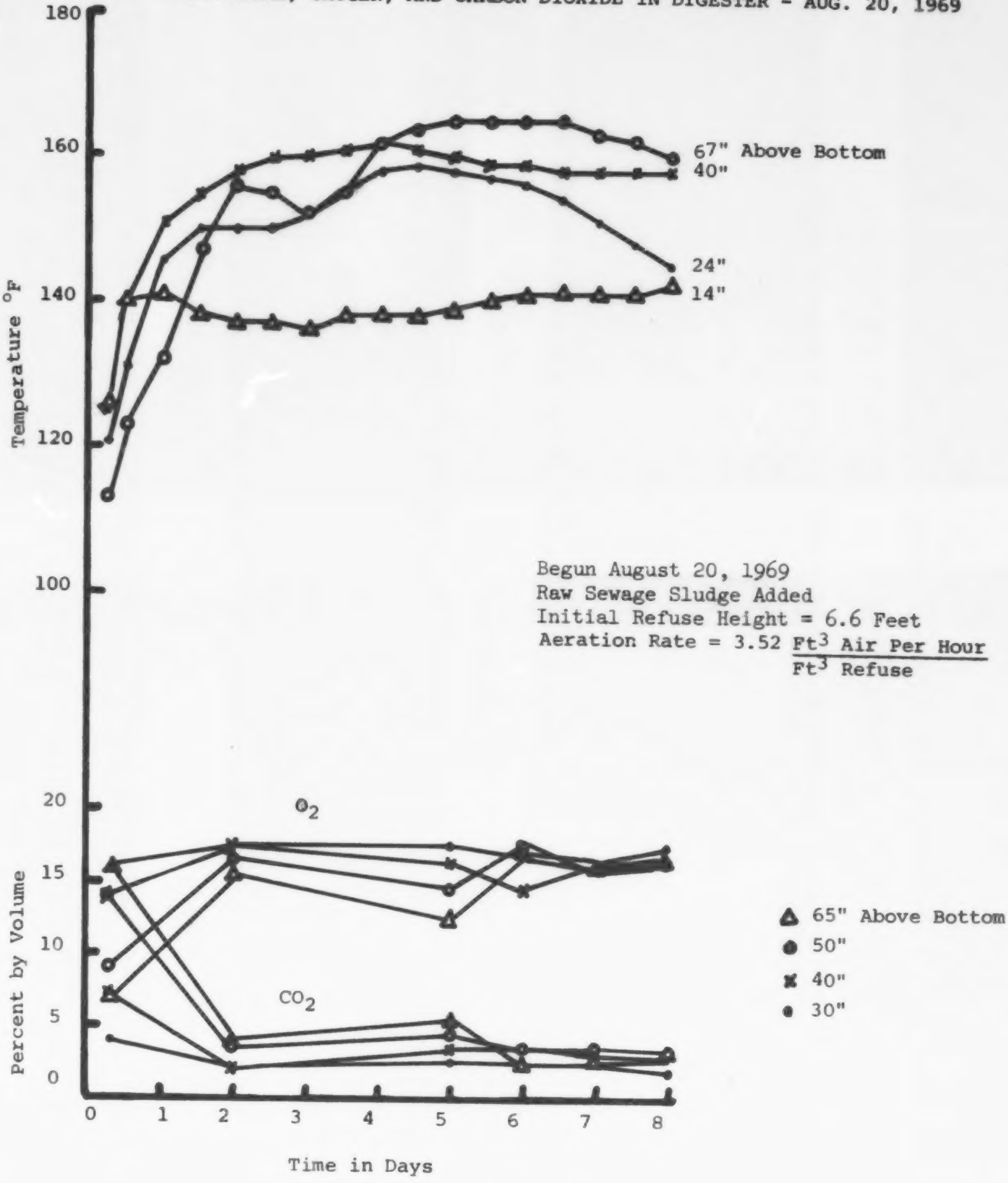
Figure 8 shows that the maximum temperature reached was 165°F; this occurred at 5 days. As usual, the oxygen and carbon dioxide concentrations were determined just before the aeration blower turned on. Oxygen concentrations were usually in excess of 15% while carbon dioxide was usually less than 5%.

By adjusting the air duct valves, an excessive air flow amounting to 1.5 times normal was fed to the refuse for the fourth experiment which was begun on September 4. The initial refuse height was 7.2 feet and the air flow was 990 cfm per tank. The resulting aeration rate was 5.32 ft^3 per hour per ft^3 of refuse.

The initial moisture content was 49%. At 8 days the moisture content was 52% at the 2 ft. and 8 ft. elevations. The moisture data show that an increase in aeration rate does not dry out the refuse. Evidently, moisture produced by the composting process will replace any that is driven off provided the initial moisture is high enough and the aeration rate is not too high.

Figure 9 shows that temperature at the 66 and 49 inch levels in particular rose rapidly and leveled off at about 1.5 days. Temperatures at other levels rose as expected. Oxygen and CO_2 concentrations stabilized in about a day as compared with 2-4 days in previous experiments.

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - AUG. 20, 1969

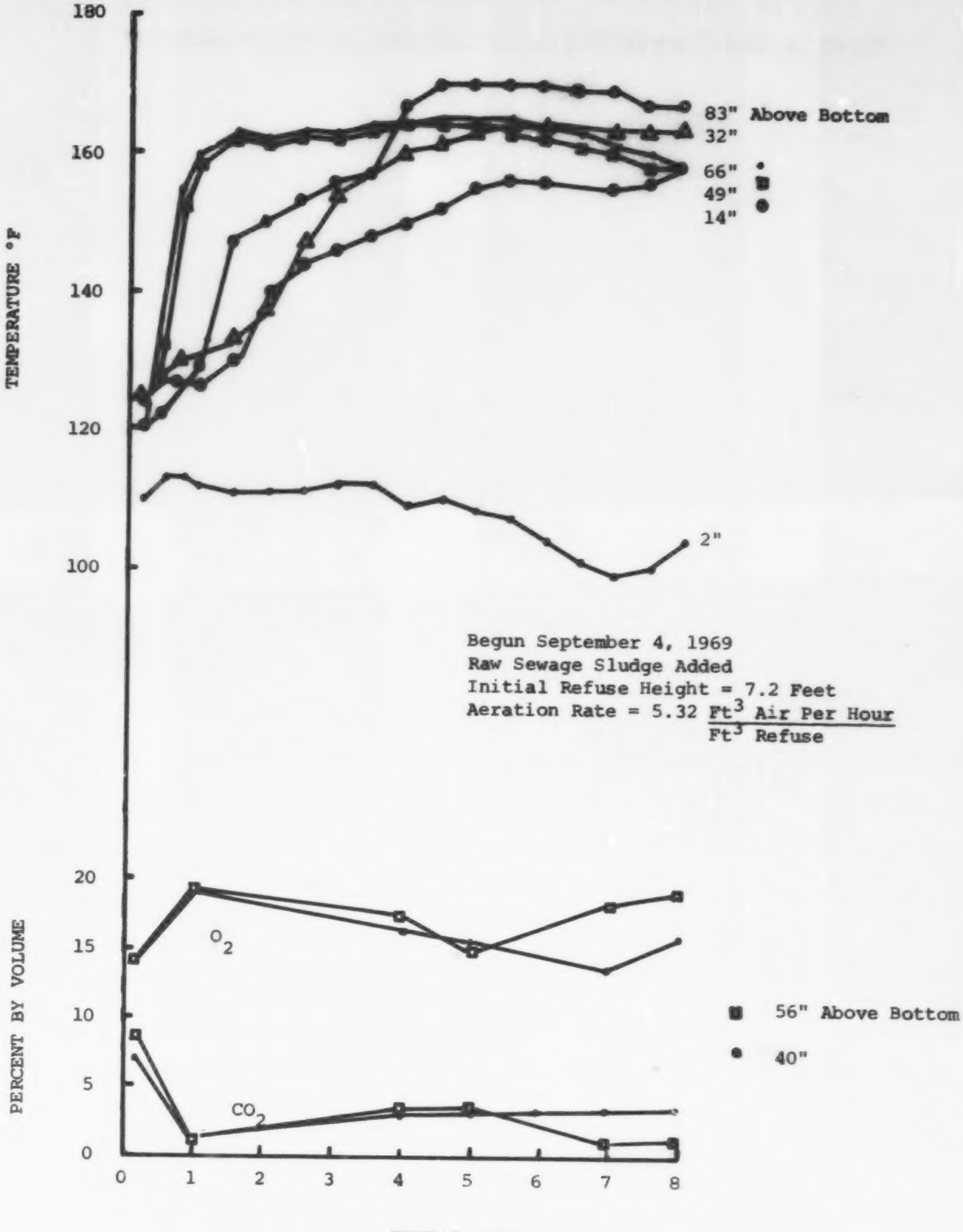


Begun August 20, 1969
Raw Sewage Sludge Added
Initial Refuse Height = 6.6 Feet
Aeration Rate = 3.52 $\frac{\text{Ft}^3 \text{ Air Per Hour}}{\text{Ft}^3 \text{ Refuse}}$

FIGURE 8

FIGURE 9

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - SEPT. 4, 1969



Begun September 4, 1969
Raw Sewage Sludge Added
Initial Refuse Height = 7.2 Feet
Aeration Rate = 5.32 $\frac{\text{Ft}^3 \text{ Air Per Hour}}{\text{Ft}^3 \text{ Refuse}}$

The fifth experiment was begun September 16 and had an air supply of 0.5 normal. The initial refuse height was 6.3 ft. with an airflow of 310 cfm per tank. An aeration rate of 1.90 ft^3 per hour per ft^3 of refuse resulted. The moisture content at the beginning was 46%.

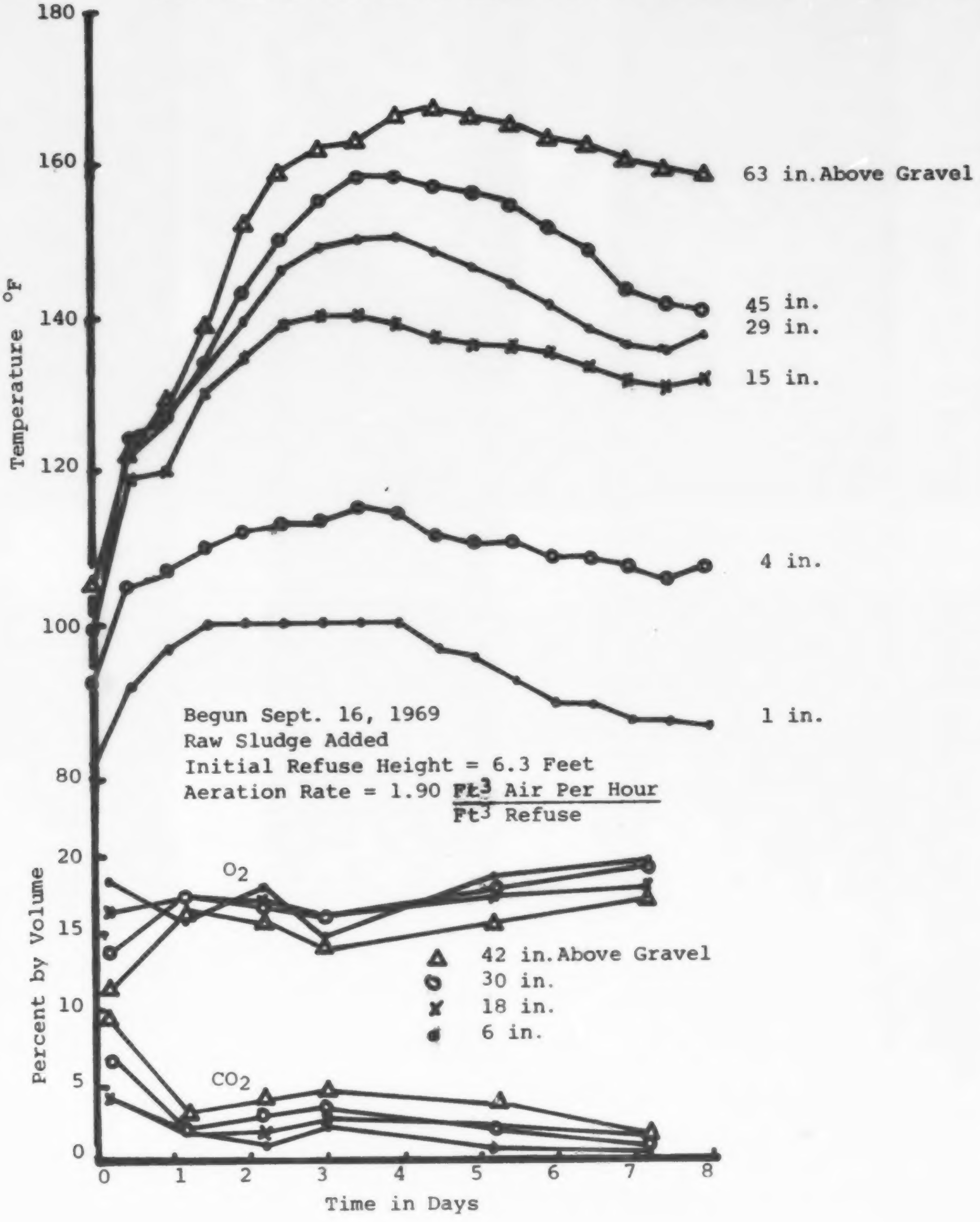
Figure 10 shows that temperature development was slow but reached 167°F at 4.5 days. Oxygen and carbon dioxide levels were maintained well.

On comparing the results of the three runs, several things became evident. The oxygen demand of the refuse-sewage sludge mix appears to be satisfied with all three of the aeration rates. It should be noted that the raw sludge used in these experiments was added at a rate of from 30 to 50 gallons per ton of refuse moistened and contained only 1.5% solids. It is estimated that addition of 110 gallons per ton of a 6% solids sludge would be required to consume all of the sludge produced by the City. The oxygen demand of this thick sludge would be considerably more than that of the dilute sludge used during these experiments.

Even though the sludge used in these experiments was dilute, there were suggestions that sludge as contrasted with water caused temperatures to rise at a faster rate and level off more quickly. In experiment 3 (Figure 8) temperatures leveled off between the second and third days; in experiment 5 (Figure 10) temperatures leveled off

FIGURE 10

TEMPERATURE, OXYGEN AND CARBON DIOXIDE IN DIGESTER - SEPT 16, 1969



Begun Sept. 16, 1969
Raw Sludge Added
Initial Refuse Height = 6.3 Feet
Aeration Rate = 1.90 $\frac{\text{Ft}^3 \text{ Air Per Hour}}{\text{Ft}^3 \text{ Refuse}}$

between the third and fourth days. Sludge was used for both experiments. By contrast, in experiment 1 (Figure 4) when no sludge was used, temperatures did not level off before days 5 and 6. This stimulated rise in temperature correlates well with the earlier findings that sludge stimulates decomposition. An exception occurred in experiment 2 (Figure 7) in which sludge was added but temperatures did not level off until days 5 or 6. However, in experiment 2 some unknown influence profoundly slowed and then increased the temperature rise. It is doubtful that the moistening agent would do this.

The 1.5 normal aeration rate resulted in faster temperature development at some levels than the normal and 0.5 normal rates. The 1.5 normal aeration rate also made temperatures more uniform throughout the mass than did the others. The faster development and increased uniformity of temperature resulting from the increased aeration rate indicate conditions for better decomposition. Whereas it is not possible to increase the air supply without changing the blower setup; it is possible to extend the aeration period. (This was done in the next experiment.)

One interesting result of the temperature observations was that little temperature rise was noted at the levels from the bottom up to four inches. (See Figures 9 and 10.) This again indicates the need for mixing the refuse sufficiently during the digestion process. It is expected that decomposition would progress very slowly at these low temperatures. Also, temperatures below 122°F (50°C) are seldom considered high enough to kill pathogens within a practical length of time.

On the other hand, temperatures attained throughout most of the digester after 2 - 3 days are far too high for optimum microbial activity. Temperatures above 131°F (55°C) limit microbial activity to only the thermophilic types. The optimum temperature range for growth of thermophiles is 131° - 140°F (55° - 60°C). The maximum temperature at which growth occurs is 167°F (75°C). Very frequently digesters operate near this temperature. This is not to say that the digesters should be operated at lower temperatures. High temperatures certainly favor rapid decomposition. Thus, it is strongly indicated that decomposition above 167°F is not a result of microbial activity.

e) Effect of Extending Aeration Time - October 27: The three previous experiments on refuse aeration have indicated that a higher aeration rate produced conditions for better decomposition. Those experiments were conducted when dilute sewage sludge was added. The addition of thick sludge was started on a regular basis in mid-October. The aeration period for the digesters was extended in anticipation of the increased oxygen demand of the thick sludge. It was extended from 16 minutes per hour to 28 minutes per hour in the test half of the digester.

An experiment designed to determine the effect of the extended aeration time on refuse decomposition was begun October 27. The study was to have run for an 8 day period. Unfortunately, the refuse was removed accidentally after 3 days and much of the value of the experiment was lost. However, those data that were collected were meaningful.

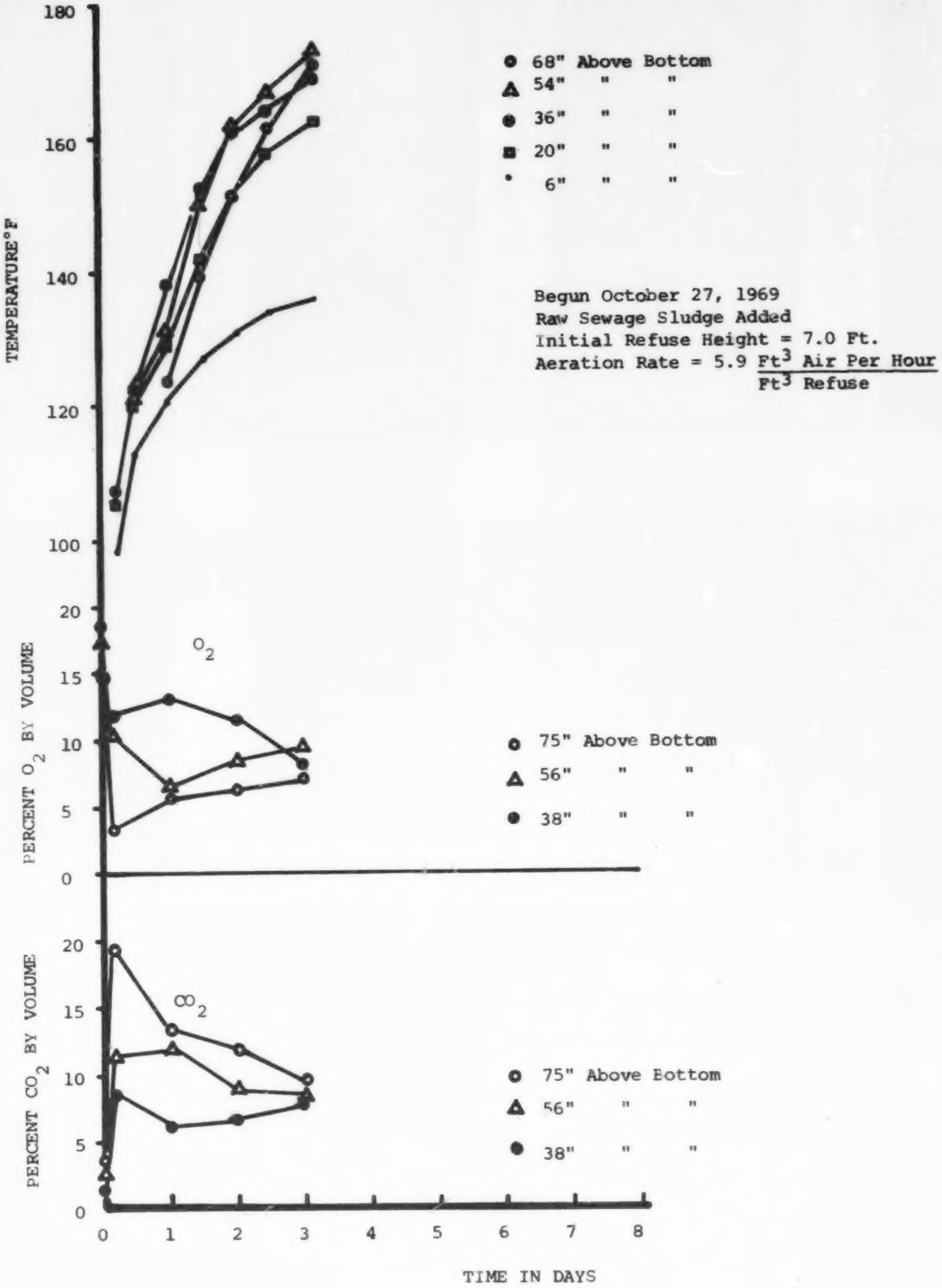
Thick sewage sludge was added to the refuse under study at a rate of 110 gallons per ton. Sludge solids ranged from 6 to 7%. The initial moisture content was about 55%. Air supply to the section of the digester containing the refuse under study was 610 cfm for 28 minutes per hour. The initial refuse height was 7.0 feet. The resulting aeration rate was 5.9 ft^3 per hour per ft^3 of refuse.

Figure 11 shows that temperatures rose quickly and that they were uniform throughout most of the depth. Temperatures were still increasing at all levels when the probe was withdrawn after 3 days. Refuse temperatures at 20 inches and above exceeded 160°F on the third day. These extraordinary temperatures gave a strong indication that decomposition was accelerated by the increased air supply and/or by the thick sludge.

The high oxygen demand of the refuse-thick sludge mixture was shown by the results of the gas measurements. Oxygen levels dropped sharply during the first 3 hours in the digester. The oxgyen concentration at the 75 inch elevation was 3.5% after 3 hours. The high concentration of sludge was evidently responsible for the rapid oxygen uptake. Oxygen concentrations recovered somewhat after the initial drop but they were far lower than normal despite the high aeration

FIGURE 81

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - OCTOBER 27, 1969



Begun October 27, 1969
Raw Sewage Sludge Added
Initial Refuse Height = 7.0 Ft.
Aeration Rate = 5.9 $\frac{Ft^3 \text{ Air Per Hour}}{Ft^3 \text{ Refuse}}$

rate. In all previous experiments, the oxygen concentrations ranged from 16 - 19% after the initial drop. In this experiment, the average oxygen concentration was about 9%.

Carbon dioxide production was high during the first 3 hours. A CO_2 concentration of 19% was measured at the 75 inch elevation after 3 hours. On the third day, CO_2 concentrations at all measured elevations dropped to about 8%.

This experiment shows the advisability of extending the aeration period for the treatment of the thick sewage sludge supplement. It appears that oxygen levels would have been quite low in the digester if the previous aeration period had been retained and thick sludge added. Anaerobic conditions might have developed and produced foul odors.

8. Curing of Compost

Although the mechanical methods of composting are considered accelerated methods, the effluents from these systems are not sufficiently decomposed to be used directly for most agricultural purposes. A curing period is required during which time the waste decomposes to a relatively stable product.

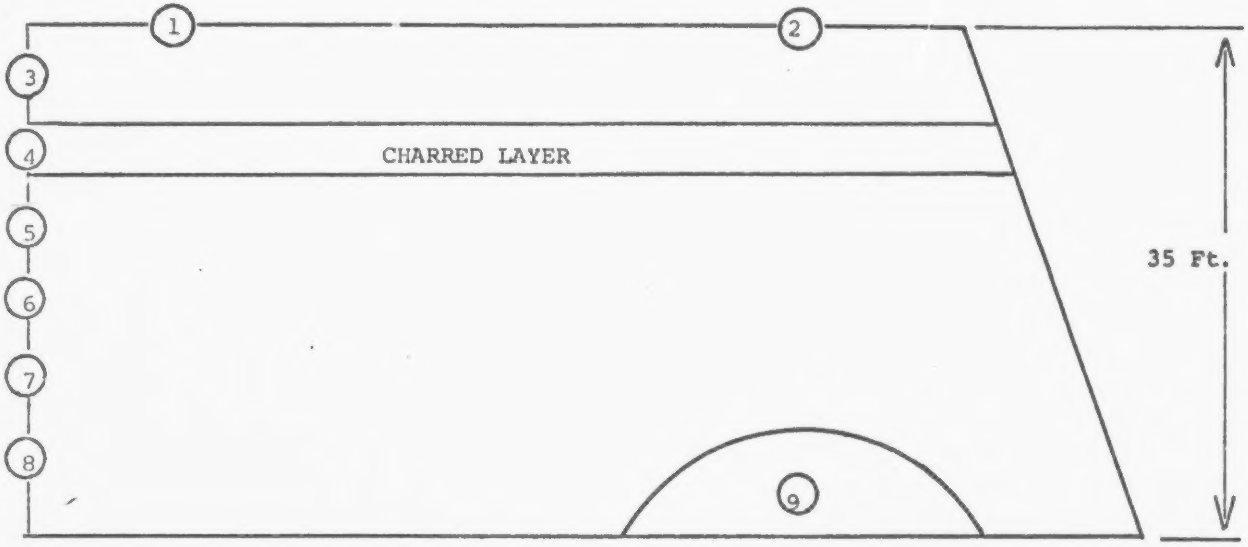
Compost was cured in large storage piles at the Gainesville Compost Plant principally because of a space shortage. It has been observed that whenever these large piles were disturbed, a strong sour odor evolved. The odor was indicative of acid accumulations which develop under anaerobic conditions of decomposition. Anaerobic decomposition is slow and inefficient, and curing must proceed for a long time before the compost is suitable for agricultural uses.

One of the large curing piles was observed for indications of decomposition. Samples were taken from several locations within the pile and analyzed for moisture, pH, and BOD. Just prior to sampling, a large quantity of compost was removed, thus exposing a cross section of the pile. Samples were taken from this newly exposed surface.

Figure 12 is a diagramatic sketch of the curing pile. The results of the analyses and the estimated age of the compost are given for each layer. The uppermost layer was a dry crust of about 6 inches deep; all other layers were approximately 7 ft. deep. The second layer was comprised of normal compost at the top and charred compost at the bottom. The charred material resulted from spontaneous combustion sometime before sampling. The zone of 12 month old compost was comprised of some of the first compost produced at the plant. Temperatures of the various zones were not taken. However, it was noticed that they were high and almost uniform except at the uppermost layer which was cool. The moisture content of most layers was too low for curing. Similarly, the acid conditions in the bottom half of the pile were unfavorable for curing and were strongly indicative of anaerobic conditions. That curing had progressed further at the top of the pile than at the

FIGURE NO. 12

MOISTURE, pH, AND BOD PROFILE OF CURING PILE



SAMPLING POINTS ARE INDICATED BY....... ① — ⑨

DUPLICATE SAMPLES ARE INDICATED BY...... ●

	ESTIMATED AGE, MONTHS	pH	MOISTURE, %	BOD, mg/g	DUPLICATE SAMPLES
①	2-4	6.8	38.1	40.8	
②	2-4	6.9	12.0	56.3	47,200 ●
③	2-4	7.0	63.5	10.3	57,600 ●
④	2-4	4.4	16.1		
⑤	5	7.1	11.0		
⑥	9	5.5	38.0	70.0	79,500 ●
⑦	11	4.5	26.0	57.6	50,400 ●
⑧	11	5.4	30.8		
⑨	12	6.4	53.4	74.0	

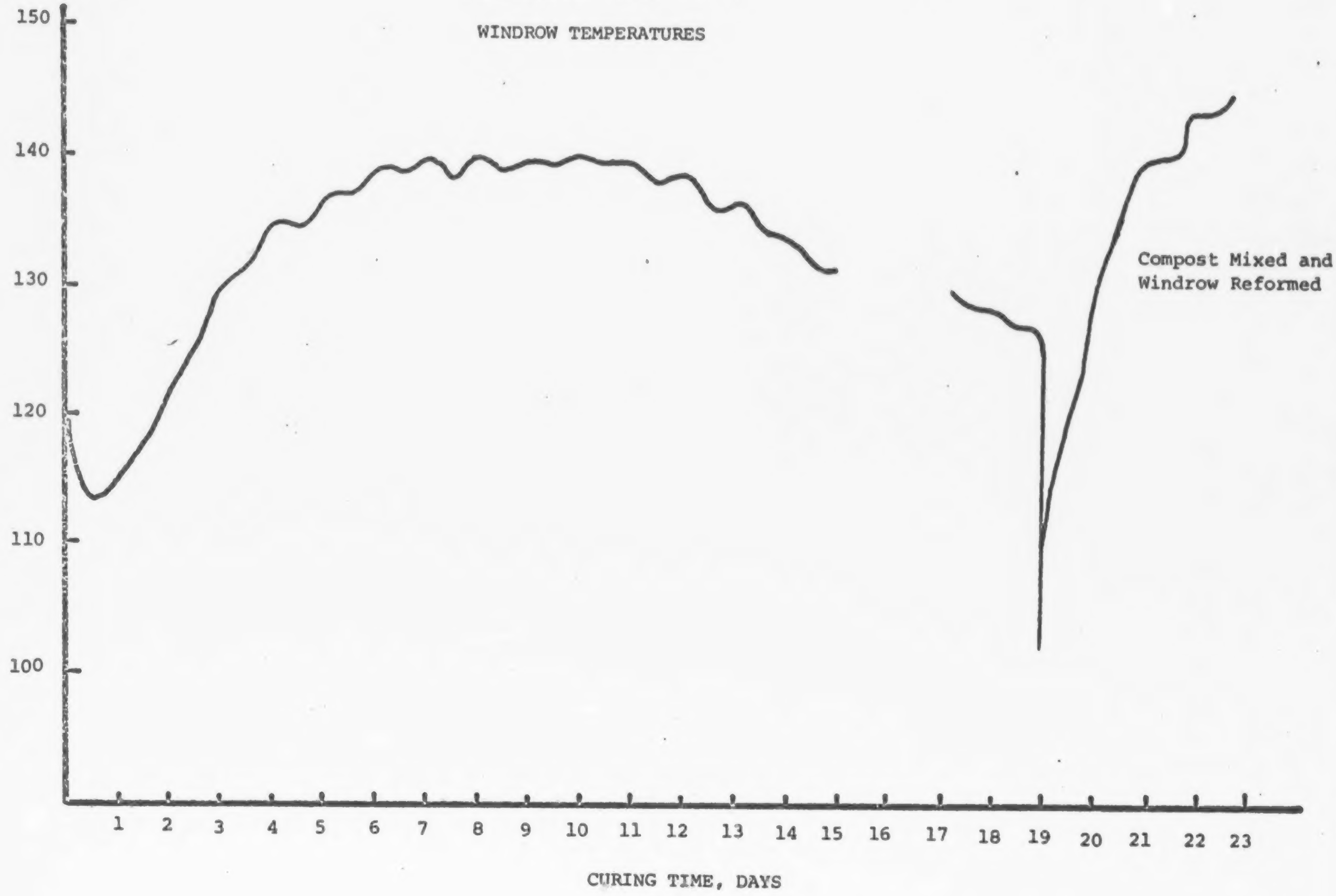
bottom is not indicated by the BOD data. Furthermore, BOD values in the range of 40 - 75 mg/g are typical of compost treated only by digestion. Thus, it appeared that most of the compost had not cured despite the long storage time and the high temperature of the pile. It follows, therefore, that uncured compost should decompose when subjectied to favorable conditions.

To test this hypothesis, some old anaerobic compost was tested for stability by an established practical method. It is known that unstable compost will decompose when it is moistened and subjected to aerobic conditions. The course of decomposition can be followed by observing the temperature of the pile which can be expected to rise at first, and then fall as the compost is either stabilized or dried. Some old unstable compost was windrowed to attain satisfactory conditions for decomposition. Six cubic yards of the most cured compost available (judged to be about 1 year old) was spread in a thin layer to cool. It rained on the second and third days raising the moisture content to 47.7 percent. On the fifth day, the compost was formed into a cone shaped pile and temperatures were measured in numerous locations. Temperatures ranged from about 115 - 122°F (46 - 50°C). The probe was then placed in its permanent position of 2 - 3 feet below the apex in the center of the pile.

Temperature data are given in Figure 13. The probe stabilized shortly before noon during the first day of curing and the timing

FIGURE NO. 13

WINDROW TEMPERATURES



of the experiment was begun. Each daily interval in Figure 2 represents the noon temperature and the midpoint between each day indicates the midnight temperature. During the first 4 days the temperature rose continually, but the rate of increase was slightly higher during the day than at night. Thereafter, temperatures rose during the day and dropped during the night. These diurnal fluctuations obviously resulted from ambient influences. The waste decomposed at a rapid rate for the first 4 days, at a lesser rate to approximately 11 days, and then at a declining rate.

On the nineteenth day, the moisture had dropped to 26.2 percent. The waste was remoistened to 42.8 percent, aerated by lifting it with the front-end loader and dropping it repeatedly, and shaped into a pile. Within minutes, the temperature started to rise and within 48 hours it surpassed the previous maximum. These temperature data clearly show that old anaerobic compost was not cured, and that it was decomposable when subsequently subjected to suitable conditions. These findings suggested further work to determine the extent of curing of freshly digested compost treated under aerobic conditions.

Two experiments were conducted to determine the extent of treatment attained during the windrow curing of fresh compost. Water had been used to moisten the waste in the normal operation of the plant at the time the work was done. The windrows constructed for this work were not turned or otherwise aerated.

In experiment 1, effluent compost was contained in Fiberglas bags which were deposited within a pile of compost constructed for exclusive experimental use. The pile consisted of effluent compost of the same age as the sample. It was sufficiently large so as to simulate actual production conditions in a windrow. A subsample was prepared for immediate analysis. Three other subsamples were placed about 18 inches beneath the surface where they remained hot and moist. Samples were removed from the pile after 6, 15, and 94 days of curing. Experiment 2 was refined somewhat to provide comparative data on raw waste, waste composted in the digester for 10 days and waste cured in a pile for 3 months. All three subsamples were derived from the same well-mixed batch of waste.

Table 6 clearly indicates that plant effluent was highly unstable and that it continued to decompose during curing. At 3 months when experiment 2 was terminated, triplicate samples contained 29.4, 31.7 and 35.3 percent moisture. Further decomposition may have been inhibited by drying.

It must be emphasized that the Fiberglas bags were placed near the surface of the curing windrows and, therefore, were subjected to optimum conditions for decomposition in an unturned windrow. When both of the most cured samples were removed from the windrows, it was observed that only a layer of compost extending from

TABLE 6

COMPARISON OF MECHANICALLY DIGESTED AND WINDROW CURED COMPOSTS

SAMPLE DESCRIPTION	C, %	N, %	C/N RATIO	BOD, ppm X 10^3	COD, mg/gm	VOLATILE SOLIDS, %	pH
			EXPERIMENT 4				
Effluent Compost	36.6	.648	56.5	34.3	-	-	-
Compost Cured 6 Days	35.8	.663	54.0	33.2	-	-	-
Compost Cured 15 Days	31.1	.620	50.1	28.8	-	-	5.8
Compost Cured 94 Days	55.0	.684	80.5	12.0	-	-	7.45
			EXPERIMENT 5				
Raw Waste	35.0	.585	59.8	70.0	1070	69.2	6.3
Compost Digested 10 Days	34.9	.621	56.2	34.4	1012	66.3	6.95
Compost Cured 3 Months	32.7	.542	60.3	6.0	940	65.9	7.15

2 inches below the surface to about 20 inches deep was warm and moist. The compost at the very surface and below 20 inches was cool, dry, and looked poorly decomposed. Therefore, the extent of curing observed in these experiments represents something near the maximum attainable, after 90 days of treatment in aerobic windrows.

This preliminary work did show the unstable nature of effluent compost. Further work was conducted to quantify decomposition in the digester and in subsequent curing in windrows. The objective of this work was to quantify the amount of decomposition accomplished in the digester and during subsequent windrow curing. The second objective was to compare the rates of curing in a well-managed windrow with that in an unmanaged windrow. The comparison was made because production compost was cured in windrows during one period of time. But, because turning and moistening equipment was not available for production purposes, the windrows were not cared for. This work should demonstrate the results of managing windrows.

The experimental plan was to follow refuse degradation from the time the refuse was put into the digester until it had been treated in a windrow for a period of two months. The temperature, oxygen and CO_2 concentrations in the refuse were monitored through much of the study along with the physical and chemical parameters.

A sample of the raw refuse was taken as it entered the digester. Part of the sample was analyzed and the rest was put into 6 Fiberglas bags and placed in the digester. The samples in the bags were removed as required for analysis after 3 and 8 days in the digester and after 1 and 2 months of windrow curing.

Two windrows were constructed to represent two sets of curing conditions. One of the windrows was turned and moistened as required. The other was not turned or moistened.

Figure 8 shows the temperatures, oxygen and CO_2 concentrations, and aeration rates in the digester. This part of the work coincided with the normal aeration rate study (Section H-7) and is described therein.

Table 7 shows the chemical analyses of the samples of raw and digested waste. The carbon content of the refuse dropped 21%, whereas the nitrogen content dropped 13%. The resulting C/N ratio reduction was about 9% for the 8 days in the digester. The net BOD reduction was 10% after 3 days and 55% after 8 days. COD and volatile solids values also dropped during the 8 day digestion period.

The original plan of the experiment was to follow the same refuse through the digester and windrow curing. Unfortunately, an equipment breakdown delayed the removal of the refuse under study. The experimental plan was to have the refuse in the digester only for

TABLE 7

DECOMPOSITION OF REFUSE IN DIGESTER AND WINDROW

Sample	Moisture %	pH	Carbon %	Nitrogen %	C/N	BOD MG/GM	COD MG/GM	Volatile Solids %
Raw Refuse	44.9	5.2	37.7	0.578	65.2	76.6	813	73.9
Digested 3 Days	44.4	5.1	31.9	0.589	54.2	69.2	998	69.8
Digested 8 Days	43.0	6.9	29.8	0.502	59.4	34.5	654	61.9
In Windrow #1 (30% Moisture)								
1 Month	51.4	5.7	29.1	0.509	57.2	25.0	678	54.3
2 Months	33.8	6.3	32.1	0.577	55.6			
In Windrow #2 (50% Moisture)								
1 Month	47.9	6.2	36.5	0.496	73.6	34.4	657	64.3
2 Months	47.1	7.0		0.545		12.8	573	59.9

NOTE: Moisture Based on Wet Weight. Other Results Based on Dry Weight.

the typical 8 day detention time. The refuse sample bags were removed at 8 days and put into 2 windrows built with ground refuse that had just come out of the digester after 10 days detention.

Windrow #1 was made with compost as received from the digester and had an initial moisture content of 30%. Windrow #2 was first moistened to 50% before being built. Both windrows were about 5 feet high. Two of the original digester sample bags were placed in each windrow at an elevation of four feet. The samples were not ground after treatment in the digester. A sample of the compost from each windrow was taken as it was made. A zero-time sample was analyzed and two sample bags were filled and placed in each windrow at four feet elevation.

Table 7 shows that the BOD reduction for this material after one month in the windrow was 27% for windrow #1, but only 1.5% for windrow #2. After two months the BOD reduction was 66% for windrow #2. The COD and volatile solids results for windrow #2 both show reductions after 2 months. Moisture was maintained well in the windrow #2 sample for 2 months. The sample in windrow #1 lost moisture after the first month and dropped to 33.8% at 2 months.

Table 8 shows the results of analyses made of the material from which the two windrows were built. By contrast, Table 7 shows the analytical results of samples contained in Fiberglas bags.

TABLE 8

DECOMPOSITION OF REFUSE IN A WINDROW

Sample	Moisture %	pH	Carbon %	Nitrogen %	C/N	BOD mg/gm	COD mg/gm	Volatile Solids %
In Windrow #1								
(30% Moisture) As Placed	29.7	7.6	35.2	0.572	61.5	35.6	667	70.0
1 Month	27.8	5.5	36.0	0.591	60.9	35.4	868	71.0
2 Months	38.4	6.1	35.8	0.560	64.0	33.1	959	72.2
In Windrow #2								
(50% Moisture) As Placed	50.0	6.6	34.7	0.537	64.6	31.8	683	67.4
1 Month	52.0	6.6	37.0	0.545	68.0	12.8	627	63.5
2 Months	47.6	6.4	30.5	0.558	54.7	6.5	788	43.8

NOTE: Moisture Based on Wet Weight. Other Results Based on Dry Weight.

The need for sufficient moisture content for curing in a windrow to occur is indicated by the results in windrows #1 and #2. Windrow #1 had only 30% moisture when constructed and 28% one month later. After two months the moisture had increased to 38%. The BOD reduction was less than 1% during the first month and only 7% at the end of two months. Windrow #2 moisture was about 50% during the same time and produced a BOD reduction of 60% for the first month and 80% by the end of two months. Moisture content was evidently the reason for the difference in the BOD reduction.

Temperature, oxygen, and carbon dioxide were measured in the windrows during the curing process. The results are shown in Figure 14. The temperature and gas were measured in the center of the windrows at elevations of 1, 2, 3, and 4 feet.

Temperatures were generally higher in windrow #1 throughout the period of observation. This fact can be attributed directly to the moisture content of each windrow. After a rapid temperature rise at all levels, windrow #1 cooled to temperatures ranging from 125°F to 145°F at 20 days. These same temperatures were maintained up to the latest readings made at 47 days. The hottest part of the windrow during this period was the lower half.

The initial temperature build up in windrow #2 was less than that in windrow #1. However, after 20 days, the temperature in windrow #2 ranged from 125°F to 141°F which was about the same

FIGURE 14

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN TWO WINDROWS - Aug. 28, 1969.

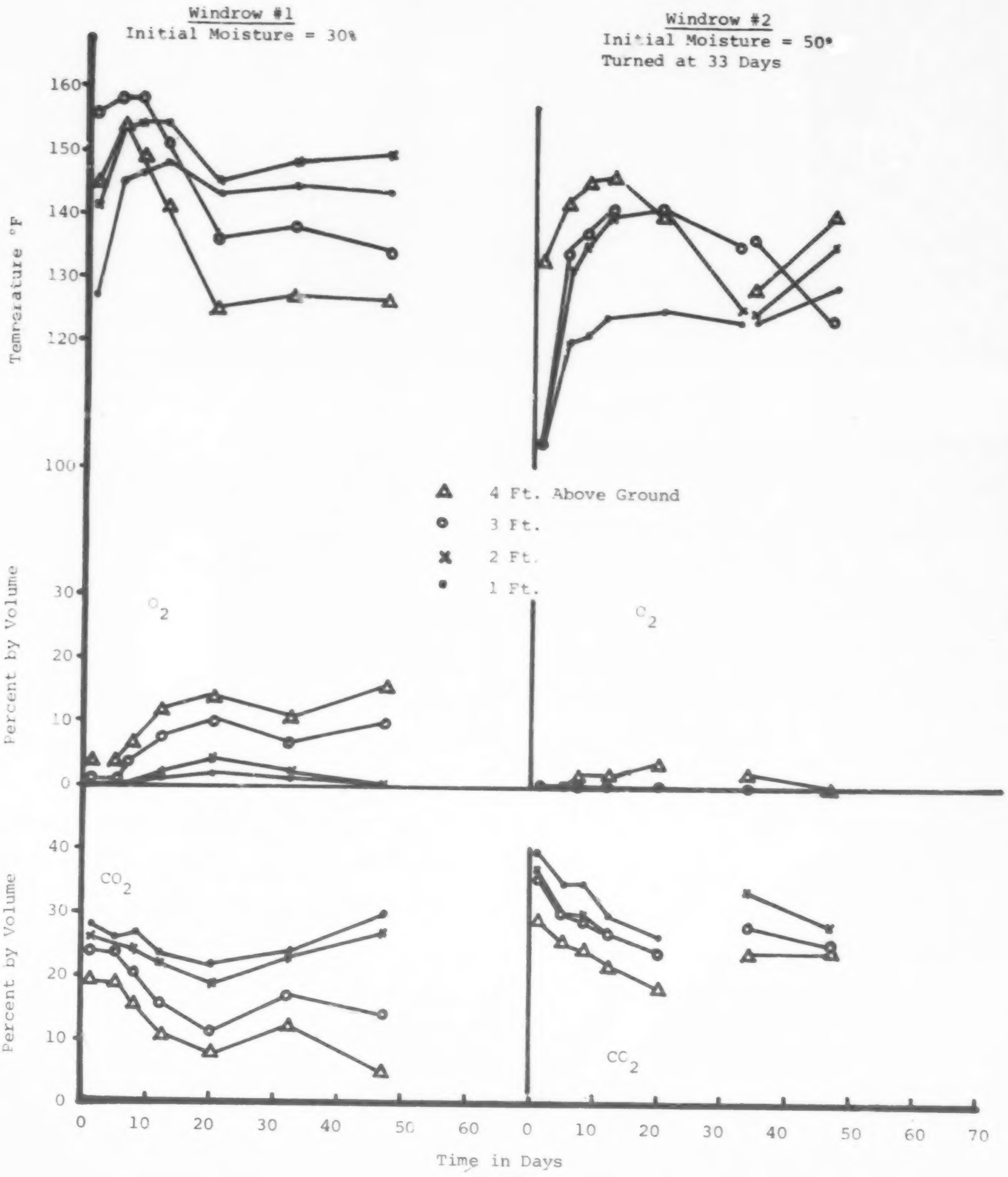
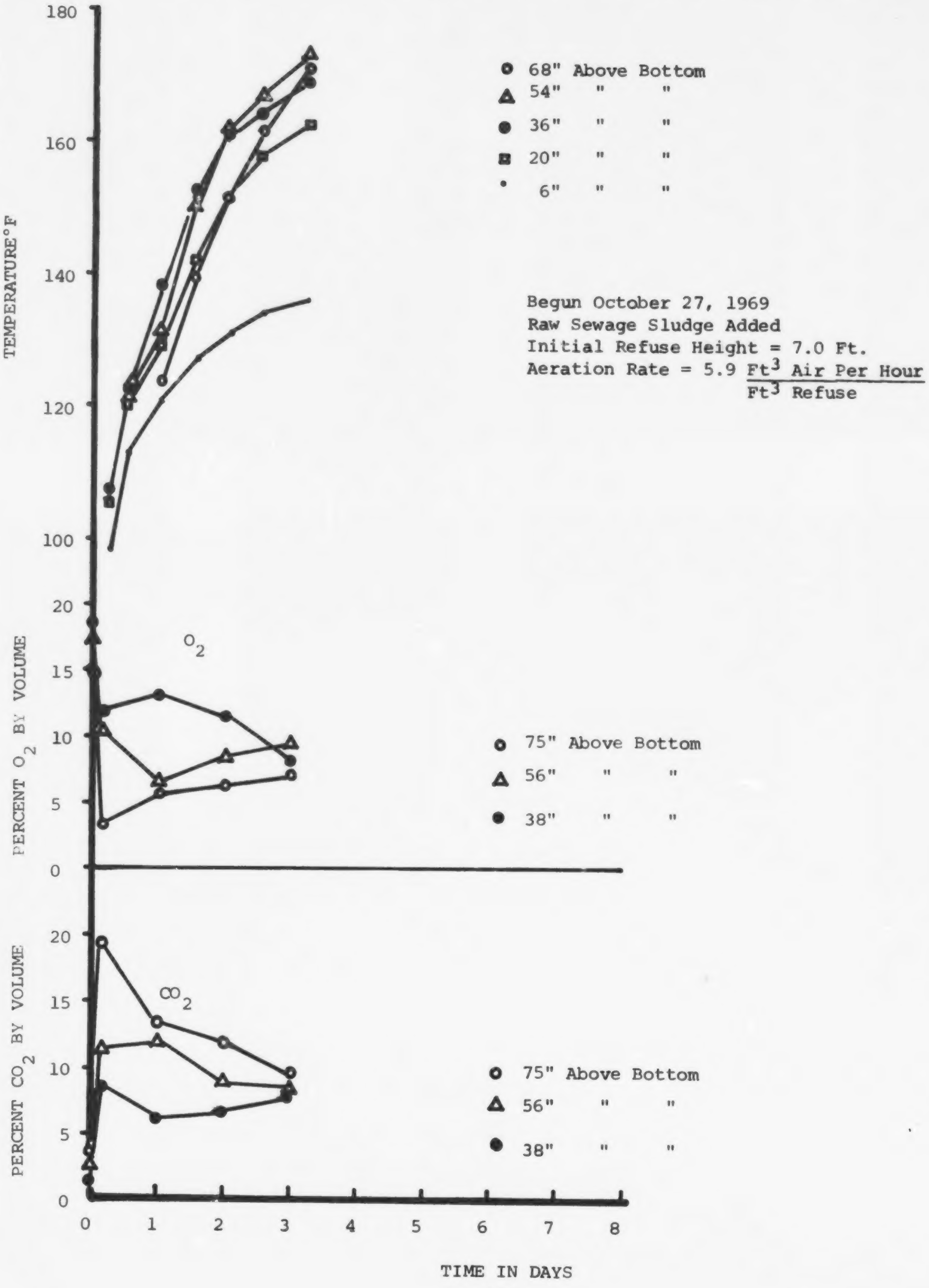


FIGURE 81

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN DIGESTER - OCTOBER 27, 1969



Begun October 27, 1969
Raw Sewage Sludge Added
Initial Refuse Height = 7.0 Ft.
Aeration Rate = 5.9 $\frac{\text{Ft}^3 \text{ Air Per Hour}}{\text{Ft}^3 \text{ Refuse}}$

rate. In all previous experiments, the oxygen concentrations ranged from 16 - 19% after the initial drop. In this experiment, the average oxygen concentration was about 9%.

Carbon dioxide production was high during the first 3 hours. A CO_2 concentration of 19% was measured at the 75 inch elevation after 3 hours. On the third day, CO_2 concentrations at all measured elevations dropped to about 8%.

This experiment shows the advisability of extending the aeration period for the treatment of the thick sewage sludge supplement. It appears that oxygen levels would have been quite low in the digester if the previous aeration period had been retained and thick sludge added. Anaerobic conditions might have developed and produced foul odors.

8. Curing of Compost

Although the mechanical methods of composting are considered accelerated methods, the effluents from these systems are not sufficiently decomposed to be used directly for most agricultural purposes. A curing period is required during which time the waste decomposes to a relatively stable product.

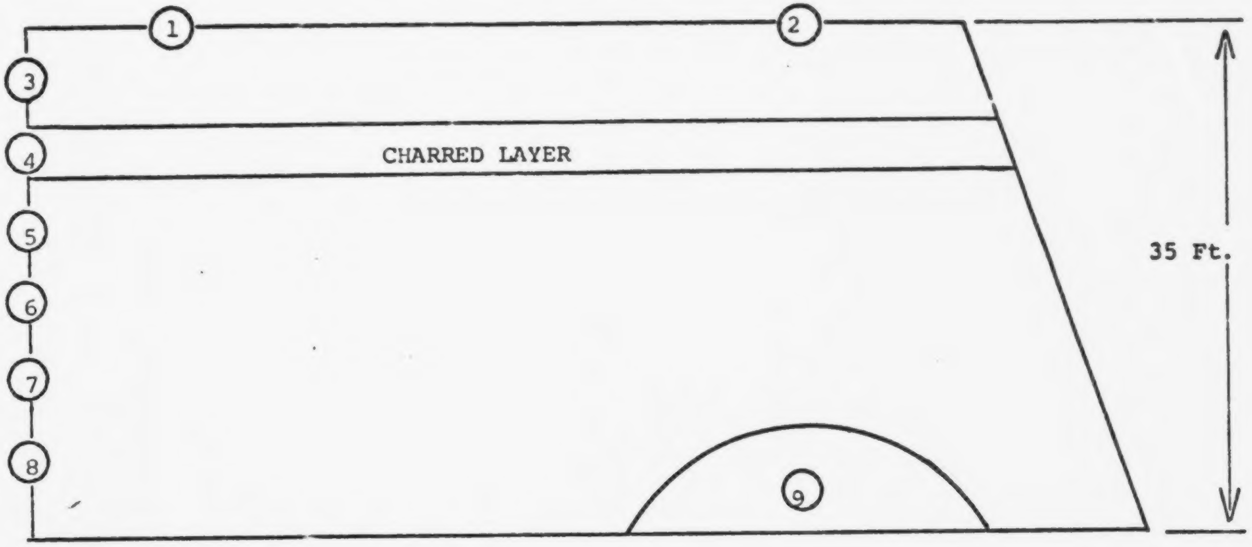
Compost was cured in large storage piles at the Gainesville Compost Plant principally because of a space shortage. It has been observed that whenever these large piles were disturbed, a strong sour odor evolved. The odor was indicative of acid accumulations which develop under anaerobic conditions of decomposition. Anaerobic decomposition is slow and inefficient, and curing must proceed for a long time before the compost is suitable for agricultural uses.

One of the large curing piles was observed for indications of decomposition. Samples were taken from several locations within the pile and analyzed for moisture, pH, and BOD. Just prior to sampling, a large quantity of compost was removed, thus exposing a cross section of the pile. Samples were taken from this newly exposed surface.

Figure 12 is a diagramatic sketch of the curing pile. The results of the analyses and the estimated age of the compost are given for each layer. The uppermost layer was a dry crust of about 6 inches deep; all other layers were approximately 7 ft. deep. The second layer was comprised of normal compost at the top and charred compost at the bottom. The charred material resulted from spontaneous combustion sometime before sampling. The zone of 12 month old compost was comprised of some of the first compost produced at the plant. Temperatures of the various zones were not taken. However, it was noticed that they were high and almost uniform except at the uppermost layer which was cool. The moisture content of most layers was too low for curing. Similarly, the acid conditions in the bottom half of the pile were unfavorable for curing and were strongly indicative of anaerobic conditions. That curing had progressed further at the top of the pile than at the

FIGURE NO. 12

MOISTURE, pH, AND BOD PROFILE OF CURING PILE



SAMPLING POINTS ARE INDICATED BY....... ① — ⑨

DUPLICATE SAMPLES ARE INDICATED BY...... ●

	ESTIMATED AGE, MONTHS	pH	MOISTURE, %	BOD, mg/g	DUPLICATE SAMPLES
①	2-4	6.8	38.1	40.8	
②	2-4	6.9	12.0	56.3	47,200 ●
③	2-4	7.0	63.5	10.3	57,600 ●
④	2-4	4.4	16.1		
⑤	5	7.1	11.0		
⑥	9	5.5	38.0	70.0	79,500 ●
⑦	11	4.5	26.0	57.6	50,400 ●
⑧	11	5.4	30.8		
⑨	12	6.4	53.4	74.0	

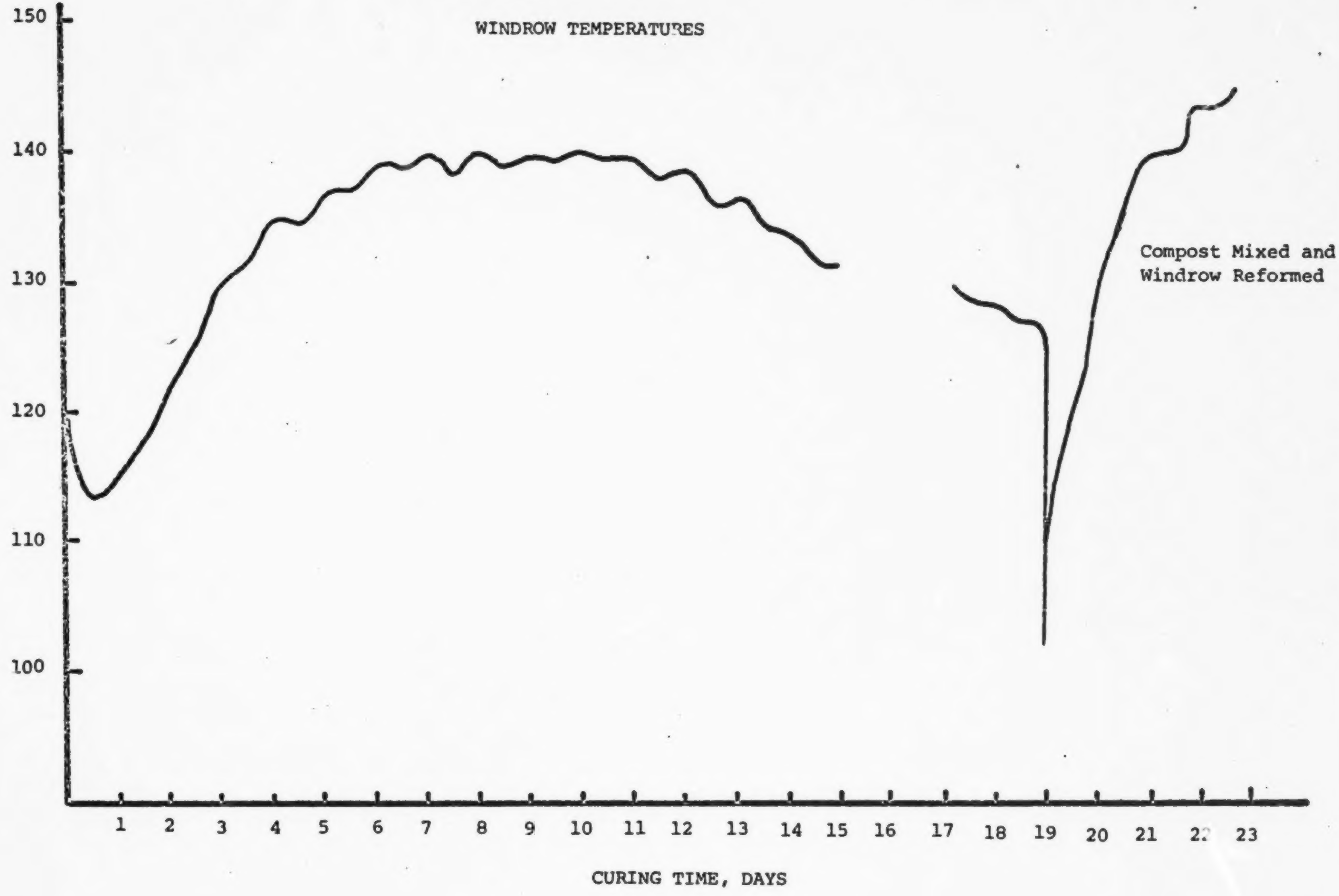
bottom is not indicated by the BOD data. Furthermore, BOD values in the range of 40 - 75 mg/g are typical of compost treated only by digestion. Thus, it appeared that most of the compost had not cured despite the long storage time and the high temperature of the pile. It follows, therefore, that uncured compost should decompose when subjectied to favorable conditions.

To test this hypothesis, some old anaerobic compost was tested for stability by an established practical method. It is known that unstable compost will decompose when it is moistened and subjected to aerobic conditions. The course of decomposition can be followed by observing the temperature of the pile which can be expected to rise at first, and then fall as the compost is either stabilized or dried. Some old unstable compost was windrowed to attain satisfactory conditions for decomposition. Six cubic yards of the most cured compost available (judged to be about 1 year old) was spread in a thin layer to cool. It rained on the second and third days raising the moisture content to 47.7 percent. On the fifth day, the compost was formed into a cone shaped pile and temperatures were measured in numerous locations. Temperatures ranged from about 115 - 122°F (46 - 50°C). The probe was then placed in its permanent position of 2 - 3 feet below the apex in the center of the pile.

Temperature data are given in Figure 13. The probe stabilized shortly before noon during the first day of curing and the timing

FIGURE NO. 13

WINDROW TEMPERATURES



of the experiment was begun. Each daily interval in Figure 2 represents the noon temperature and the midpoint between each day indicates the midnight temperature. During the first 4 days the temperature rose continually, but the rate of increase was slightly higher during the day than at night. Thereafter, temperatures rose during the day and dropped during the night. These diurnal fluctuations obviously resulted from ambient influences. The waste decomposed at a rapid rate for the first 4 days, at a lesser rate to approximately 11 days, and then at a declining rate.

On the nineteenth day, the moisture had dropped to 26.2 percent. The waste was remoistened to 42.8 percent, aerated by lifting it with the front-end loader and dropping it repeatedly, and shaped into a pile. Within minutes, the temperature started to rise and within 48 hours it surpassed the previous maximum. These temperature data clearly show that old anaerobic compost was not cured, and that it was decomposable when subsequently subjected to suitable conditions. These findings suggested further work to determine the extent of curing of freshly digested compost treated under aerobic conditions.

Two experiments were conducted to determine the extent of treatment attained during the windrow curing of fresh compost. Water had been used to moisten the waste in the normal operation of the plant at the time the work was done. The windrows constructed for this work were not turned or otherwise aerated.

In experiment 1, effluent compost was contained in Fiberglas bags which were deposited within a pile of compost constructed for exclusive experimental use. The pile consisted of effluent compost of the same age as the sample. It was sufficiently large so as to simulate actual production conditions in a windrow. A subsample was prepared for immediate analysis. Three other subsamples were placed about 18 inches beneath the surface where they remained hot and moist. Samples were removed from the pile after 6, 15, and 94 days of curing. Experiment 2 was refined somewhat to provide comparative data on raw waste, waste composted in the digester for 10 days and waste cured in a pile for 3 months. All three subsamples were derived from the same well-mixed batch of waste.

Table 6 clearly indicates that plant effluent was highly unstable and that it continued to decompose during curing. At 3 months when experiment 2 was terminated, triplicate samples contained 29.4, 31.7 and 35.3 percent moisture. Further decomposition may have been inhibited by drying.

It must be emphasized that the Fiberglas bags were placed near the surface of the curing windrows and, therefore, were subjected to optimum conditions for decomposition in an unturned windrow. When both of the most cured samples were removed from the windrows, it was observed that only a layer of compost extending from

TABLE 6

COMPARISON OF MECHANICALLY DIGESTED AND WINDROW CURED COMPOSTS

SAMPLE DESCRIPTION	C, %	N, %	C/N RATIO	BOD, ppm X 10^3	COD, mg/gm	VOLATILE SOLIDS, %	pH
			EXPERIMENT 4				
Effluent Compost	36.6	.648	56.5	34.3	-	-	-
Compost Cured 6 Days	35.8	.663	54.0	33.2	-	-	-
Compost Cured 15 Days	31.1	.620	50.1	28.8	-	-	5.8
Compost Cured 94 Days	55.0	.684	80.5	12.0	-	-	7.45
			EXPERIMENT 5				
Raw Waste	35.0	.585	59.8	70.0	1070	69.2	6.3
Compost Digested 10 Days	34.9	.621	56.2	34.4	1012	66.3	6.95
Compost Cured 3 Months	32.7	.542	60.3	6.0	940	65.9	7.15

2 inches below the surface to about 20 inches deep was warm and moist. The compost at the very surface and below 20 inches was cool, dry, and looked poorly decomposed. Therefore, the extent of curing observed in these experiments represents something near the maximum attainable, after 90 days of treatment in aerobic windrows.

This preliminary work did show the unstable nature of effluent compost. Further work was conducted to quantify decomposition in the digester and in subsequent curing in windrows. The objective of this work was to quantify the amount of decomposition accomplished in the digester and during subsequent windrow curing. The second objective was to compare the rates of curing in a well-managed windrow with that in an unmanaged windrow. The comparison was made because production compost was cured in windrows during one period of time. But, because turning and moistening equipment was not available for production purposes, the windrows were not cared for. This work should demonstrate the results of managing windrows.

The experimental plan was to follow refuse degradation from the time the refuse was put into the digester until it had been treated in a windrow for a period of two months. The temperature, oxygen and CO_2 concentrations in the refuse were monitored through much of the study along with the physical and chemical parameters.

A sample of the raw refuse was taken as it entered the digester. Part of the sample was analyzed and the rest was put into 6 Fiberglas bags and placed in the digester. The samples in the bags were removed as required for analysis after 3 and 8 days in the digester and after 1 and 2 months of windrow curing.

Two windrows were constructed to represent two sets of curing conditions. One of the windrows was turned and moistened as required. The other was not turned or moistened.

Figure 8 shows the temperatures, oxygen and CO_2 concentrations, and aeration rates in the digester. This part of the work coincided with the normal aeration rate study (Section H-7) and is described therein.

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The original plan of the experiment was to follow the same refuse through the digester and windrow curing. Unfortunately, an equipment breakdown delayed the removal of the refuse under study. The experimental plan was to have the refuse in the digester only for

TABLE 7

DECOMPOSITION OF REFUSE IN DIGESTER AND WINDROW

Sample	Moisture %	pH	Carbon %	Nitrogen %	C/N	BOD MG/GM	COD MG/GM	Volatile Solids %
Raw Refuse	44.9	5.2	37.7	0.578	65.2	76.6	813	73.9
Digested 3 Days	44.4	5.1	31.9	0.589	54.2	69.2	998	69.8
Digested 8 Days	43.0	6.9	29.8	0.502	59.4	34.5	654	61.9
In Windrow #1 (30% Moisture)								
1 Month	51.4	5.7	29.1	0.509	57.2	25.0	678	54.3
2 Months	33.8	6.3	32.1	0.577	55.6			
In Windrow #2 (50% Moisture)								
1 Month	47.9	6.2	36.5	0.496	73.6	34.4	657	64.3
2 Months	47.1	7.0		0.545		12.8	573	59.9

NOTE: Moisture Based on Wet Weight. Other Results Based on Dry Weight.

the typical 8 day detention time. The refuse sample bags were removed at 8 days and put into 2 windrows built with ground refuse that had just come out of the digester after 10 days detention.

Windrow #1 was made with compost as received from the digester and had an initial moisture content of 30%. Windrow #2 was first moistened to 50% before being built. Both windrows were about 5 feet high. Two of the original digester sample bags were placed in each windrow at an elevation of four feet. The samples were not ground after treatment in the digester. A sample of the compost from each windrow was taken as it was made. A zero-time sample was analyzed and two sample bags were filled and placed in each windrow at four feet elevation.

Table 7 shows that the BOD reduction for this material after one month in the windrow was 27% for windrow #1, but only 1.5% for windrow #2. After two months the BOD reduction was 66% for windrow #2. The COD and volatile solids results for windrow #2 both show reductions after 2 months. Moisture was maintained well in the windrow #2 sample for 2 months. The sample in windrow #1 lost moisture after the first month and dropped to 33.8% at 2 months.

Table 8 shows the results of analyses made of the material from which the two windrows were built. By contrast, Table 7 shows the analytical results of samples contained in Fiberglas bags.

TABLE 8

DECOMPOSITION OF REFUSE IN A WINDROW

Sample	Moisture %	pH	Carbon %	Nitrogen %	C/N	BOD mg/gm	COD mg/gm	Volatile Solids %
In Windrow #1								
(30% Moisture) As Placed	29.7	7.6	35.2	0.572	61.5	35.6	667	70.0
1 Month	27.8	5.5	36.0	0.591	60.9	35.4	868	71.0
2 Months	38.4	6.1	35.8	0.560	64.0	33.1	959	72.2
In Windrow #2								
(50% Moisture) As Placed	50.0	6.6	34.7	0.537	64.6	31.8	683	67.4
1 Month	52.0	6.6	37.0	0.545	68.0	12.8	627	63.5
2 Months	47.6	6.4	30.5	0.558	54.7	6.5	788	43.8

NOTE: Moisture Based on Wet Weight. Other Results Based on Dry Weight.

The need for sufficient moisture content for curing in a windrow to occur is indicated by the results in windrows #1 and #2. Windrow #1 had only 30% moisture when constructed and 28% one month later. After two months the moisture had increased to 38%. The BOD reduction was less than 1% during the first month and only 7% at the end of two months. Windrow #2 moisture was about 50% during the same time and produced a BOD reduction of 60% for the first month and 80% by the end of two months. Moisture content was evidently the reason for the difference in the BOD reduction.

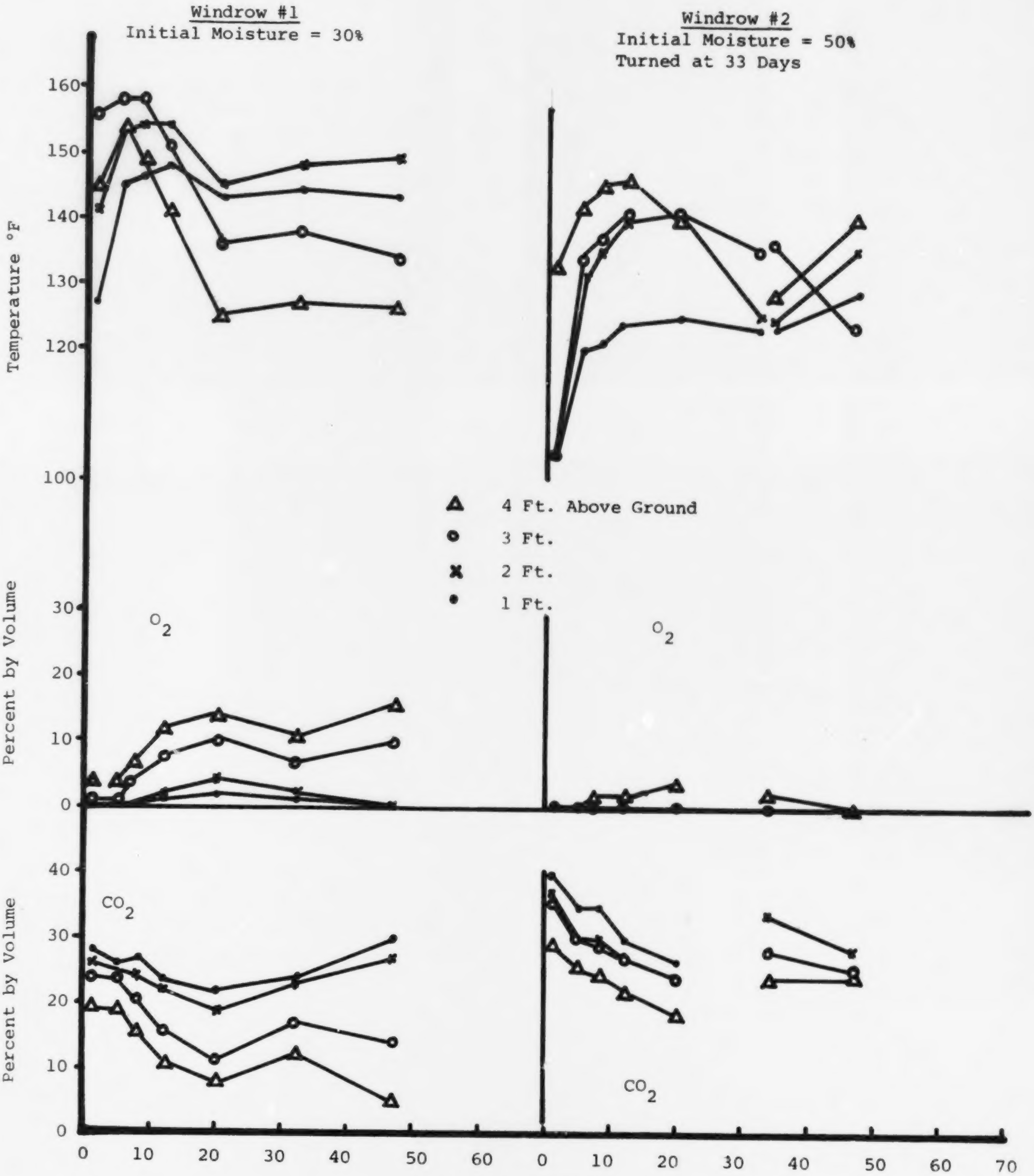
Temperature, oxygen, and carbon dioxide were measured in the windrows during the curing process. The results are shown in Figure 14. The temperature and gas were measured in the center of the windrows at elevations of 1, 2, 3, and 4 feet.

Temperatures were generally higher in windrow #1 throughout the period of observation. This fact can be attributed directly to the moisture content of each windrow. After a rapid temperature rise at all levels, windrow #1 cooled to temperatures ranging from 125°F to 145°F at 20 days. These same temperatures were maintained up to the latest readings made at 47 days. The hottest part of the windrow during this period was the lower half.

The initial temperature build up in windrow #2 was less than that in windrow #1. However, after 20 days, the temperature in windrow #2 ranged from 125°F to 141°F which was about the same

FIGURE 14

TEMPERATURE, OXYGEN, AND CARBON DIOXIDE IN TWO WINDROWS - Aug. 28, 1969.



as in windrow #1. The interesting thing is that the upper part of windrow #2 was the warmest at 20 days while the lower part of windrow #1 was the warmest at 20 days.

Oxygen levels were consistently higher in windrow #1 than in windrow #2. Windrow #1 was mostly aerobic while windrow #2 was mostly anaerobic.

Rainfall was 4.2 inches during the one week period following the construction of the windrows. This heavy rain apparently penetrated the windrows. The dry windrow (#1) was not moistened much by the rain. Water was observed flowing from the base of the wet windrow (#2) after the rains. It was felt that the turning of windrow #2 to restore aerobic conditions would require too much time to be practical. The sample bags and temperature and gas probes would have to be removed and replaced each time the windrow was turned. The conditions in windrow #2 where the sample bags were located were aerobic and it was decided to leave the windrow as it was. The windrow was turned once at 33 days, but no improvement in oxygen content was noticed.

Foul odors common to anaerobic compost were observed upon sampling the gas in windrow #2. Nevertheless, Table 8 shows that decomposition was much more extensive when the waste contained 50% moisture as compared with 30% moisture. This is shown by reductions in C/N ratios, BOD and volatile solids values. The significance of higher temperatures resulting from the decomposition of refuse containing only 30% moisture is not understood. Better decomposition at the higher moisture content is also shown by the greater oxygen demand. It would appear that this curing experiment came very close to anaerobic decomposition. Apparently the best decomposition will occur when the initial moisture content is less than 50% and/or the windrow is turned frequently.

When it became known that compost was not being cured in large storage piles, a site was acquired for the curing of compost in windrows. The windrows were constructed by dumping compost from the end of a moving truck. This compost had been digested for 6 - 8 days. Either water or digested sewage sludge had been used as moistening agents prior to digestion. The resulting windrows were about 5 feet high and about 7 feet wide at the base. No attempt was made to turn or moisten these windrows. No attempt was made to conduct a controlled study of these windrows because this was done previously on special experimental windrows conveniently located near the laboratory. However, they were observed periodically for about 1.5 years to estimate the results of unmanaged windrowing.

Flies or rodents were never seen at the windrow site although there was a distinct green compost odor after each heavy rain.

A sample of compost was taken from within a 3 month old windrow about 2 feet below the top surface. It had the following analysis: carbon - 31.1%, nitrogen - 0.595%, C/N ratio - 52.3, BOD - 58.9 mg/g, COD - 7724 mg/g, volatile solids - 68.7%, moisture content - 48.4%. These values are typical of compost which had been digested for 8 days. Thus, it appears that after 3 months of unmanaged windrowing the compost had not cured much. Temperatures of curing compost were taken at various elevations in a 3 month old and a 2 week old windrow. The following compilation shows the results:

TEMPERATURES AT STIPULATED ELEVATIONS, °F

Elevation, Ft.	3 Month Windrow	2 Week Windrow
1	172	180
2	167	176
3	158	176
4	140	167

Temperatures in the 2 week windrow are about the same as those developed in the digester. Even after three months the temperatures remained sufficiently high to either kill or prohibit the growth of pathogenic microorganisms.

Subsequently, a windrow estimated to be 9 - 10 months old was observed. At a point 6 inches below the top surface, the temperature was 99°F. At a point 18 inches below the surface, the temperature was 102°F. The ambient temperature was 84°F. The compost at the surface of the windrow was very dry and had a distinct grey color. A very profuse growth of a yellow to cream colored fungus permeated the compost from 1/2 in. to a depth of about 6 in. below the entire surface. Below this there was no more visible fungal growth and the compost was very wet and dark. A pleasant odor of leaf mold was emitted when the surface of the windrow was disturbed.

Windrows of 14 - 15 months old were deminished to only 1 1/2 feet high from their original height of about 5 feet. The color of the compost was dark black. It had a faint earth-like odor. Most windrows of this age were covered with a very heavy plant growth thought to be Bermuda grass.

From these observations, it appears that partially digested compost can be cured in unmanaged windrows, if time and space permit. The only apparent nuisance was an odor of green compost after heavy rains. It must be recognized that results noted here may not occur in other climates.

9. Bulk Density of Compost in Storage Pile

Digested, reground compost was stored in large piles for a period of time. Some of the piles were as high as 35 feet and it is likely that the compost at the bottom is highly compacted. Information on the bulk density of compacted compost may be useful to those considering the transporting of compost.

Samples were taken March 10, 1969, from the lower part of the storage pile. Three samples were carefully collected in the form of chunks and put in thin plastic bags. The weight and volume of the samples were calculated.

The volume measurement was made with the compost chunk in the plastic bag. A 3500 ml. beaker was filled to the point of over flowing. The excess air was removed from the sample bag with a vacuum pump and the bag immersed in the beaker causing an amount of water equal to the volume of the sample to be displaced from the beaker.

The sample was removed, the beaker was again filled to the point of overflowing, and the amount of water required noted. The results follow:

Sample Number	Weight, grams	Volume ml.	Bulk Density lb/yd^3
1	215.7	465	780
2	702.4	1406	836
3	620.0	1139	920

The average value of bulk density was 845 lb/yd^3. The bulk density values varied about ± 9 percent so the resulting value is only approximate. The moisture content within the storage piles has ranged from 30 - 45 percent. Somewhat greater bulk density would be expected in the lower part of the storage pile because of compaction.

10. Process Evaluation - Miscellaneous

Generally, the objective of evaluating the composting process was to determine what was accomplished. When it was shown that some part of the process was poor, an alternative was selected, and then it was evaluated. The use of windrows for curing compost in place of the original storage pile is an example of the accomplishments of process evaluation. Various minor aspects of the composting process were evaluated.

a) Effect of Refluxing on Waste Decomposition: Several investigators have shown that the seeding of refuse with special microbial cultures or various natural inocula such as animal manures failed to enhance the decomposition of refuse. The return of some freshly composted waste to a similar raw refuse might provide a population of microorganisms more specifically adapted to the waste being treated than a population from another source. Accordingly, decomposition might be enhanced or accelerated. This hypothesis was tested in one experiment.

Approximately eight cubic feet of freshly ground raw refuse was placed on a concrete slab and made as homogeneous as possible by mixing with hand tools. About one-half of a cubic foot was subsampled and prepared for analysis to characterize raw refuse. A Fiberglas bag was filled with approximately one cubic foot of raw waste and it was placed in the digester. Refuse which had been composted for 10 days was blended with the remaining raw refuse on the concrete slab. The mixture contained approximately 80 percent raw refuse and 20 percent compost. A subsample was taken for analysis to characterize the blend before further treatment. Two other Fiberglas bags were each filled with approximately one cubic foot of blend and were placed in the digester adjacent to the bag of raw refuse. The three bags were left in the digester for 13 days. Detailed results reported previously(6) were very inconclusive. There is little to indicate that refluxing enhanced the decomposition of refuse.

b) Nitrogen Leaching from Compost Piles: The leaching of nitrogen compounds from piles of compost to the soil may result in serious pollution of ground water. This is known to be a problem in animal feed lots, for example. Nitrogen compounds leaching from the source to the underlying soil are converted to nitrate compounds which are very mobile in the soil. Nitrates which are not assimulated by living plants rapidly descend to the water table. Water thus contaminated and consumed by infants may give rise to the disease known as infant methemoglobinemia, which can be fatal.

The soil underneath the bulk storage pile was found to be almost black in color suggesting a type of soil or possibly ground water contamination. Compost had been stored in this pile for about 1.5 years. Soil samples were taken from two locations near the pile and from two other places located at least 100 yards from the pile. One sample was taken from each of the four locations about 2 feet below the surface. Samples were analyzed in triplicate for Kjeldahl nitrogen by the same method used for refuse and compost. The following compilation shows the average Kjeldahl nitrogen contents of each of four soil samples:

KJELDAHL NITROGEN, %

Near Storage Pile	100 Yards from Pile
.0407	.0382
.0534	.0153

Although this was not an exhaustive study of contamination from compost piles, it does suggest a potential for nitrate contamination of ground water from improperly stored compost. It is likely that compost stored in windrows would absorb more rain water and thus reduce the leaching of nitrogen from compost.

c) Total Bacterial Counts: Numbers of bacteria in refuse as a function of treatment time might indicate the rate of refuse decomposition. It can be expected that the number of bacteria will increase with time of treatment.

Bacterial counts were made on raw ground refuse and periodically on the same refuse as it was being composted. Counts were made of the bacterial population which decompose refuse rather than those which are pathogenic as was done in another section of this report. Approximately one cubic foot of raw ground refuse was obtained for this study. Two grams of this refuse was comminuted with 200 ml of phosphate buffer in a Waring blender for 5 minutes. The buffer consisted of 1 g each of K_2HPO_4 and KH_2PO_4 per 1000 ml of distilled water. The suspension was diluted and plated on Bacto Tryptone Glucose Extract Agar (TGEA). This agar is not selective and therefore a great number of bacterial types will grow on it The agar plates were put into a 99°F (37°C) incubator for 24 hours after which the colonies were counted.

The original quantity of refuse was placed in a Fiberglas bag which in turn was placed in the digester about 2 ft. below the surface of the refuse. The refuse was sampled periodically, plated as described above, and returned to the digester for further treatment. Plates made from raw refuse and refuse composted for one-half and one day were put in a 99°F incubator. Plates made from subsequent samples were placed in a 122°F (50°C) incubator. These temperatures generally correspond with those in the digester as refuse digestion progresses. Thus, the general mesophilic population was determined on the untreated refuse and that which was composted for one day. The general thermophilic population was determined on refuse which had been composted for more than one day. The following compilation shows that the general bacterial population decreased with increased duration of composting.

BACTERIAL POPULATION OF COMPOSTING REFUSE

Duration of Composting, Days	Numbers of Bacteria per g, dry wt.
0	3.4×10^7
0.5	2.5×10^7
1	1.7×10^7
3.5	1.8×10^6
4	2.6×10^5
5	2.9×10^5
6	2.0×10^5
7.5	2.0×10^4

The significance of these results is not known. Further work is needed before it can be concluded that the number of bacteria does actually decrease with the duration of composting. It is possible that the high temperatures developed in the digesters may have reduced the numbers of organisms which were decomposing refuse. It is generally known that a temperature of 131°F (55°C) restricts life to only a few forms of thermophilic bacteria and fungi. Temperatures in excess of 131°F greatly deminishes the activity of these thermophiles. Biological activity above approximately 140°F (60°C) is not known. Nevertheless, composting is frequently accomplished at 160-180°F (72-82°C). This implies a conversion from a biological process to a chemical auto-oxidation process.

11. Arthropod and Rodent Control

Control programs for arthropods and rodents are greatly dependent on the animal's behavior and ecology. Based on an animal's habits, seasonal population changes, and life cycles, a practical method of control may be devised. Such a study was undertaken to determine these and other ecological characteristics of the fly population associated with the Gainesville Compost Plant. The fly population was selected for this investigation because flies are present in large numbers and are a short flight away from neighboring homes. Rodents and other arthropods are insignificant in numbers and are easily controlled with pesticides.

a) Immature Flies: Fly larvae are present in incoming refuse in considerable numbers during the warmer months. Many of these larvae migrate from the refuse stored in the receiving area and cause annoyance to workers, particularly those in the maintenance shop located next to the receiving area. Other larvae reach protected areas in which they transform into adults. A larval sampling program was conducted from January - November, 1969. The objective of this program was to develop procedures for reducing the larvae population and the ensuing adult flies. To accomplish this objective, larvae which were brought to the plant were identified as to species and the larval population was characterized as to species composition. In addition, a population factor was developed. This factor is a mathematical expression which might be used for the estimation of the size of the incoming larval population. It is based on sampling a known fraction of the incoming population in a one-foot-square box-like container. The work described in this report shows how the total incoming larval population was determined and how the population factor was used to estimate this population. Table 9 shows larval types and counts from incoming refuse during the period of January - November, 1969.

In order to determine the credibility and value of the population factor, it was necessary to establish the percentage of the total population that was trapped in the larval sampling program and the reliability of this procedure. Visual observations indicated that

TABLE 9

FLY LARVAE FOUND IN INCOMING REFUSE

Week Of:		No. Caught	No. Examined	Species - Percent Examined				
				Phaenicia sp.	Hermetia illucens	Callitroga macellaria	Musca domestica	Sarcophaga sp.
Jan.	12	0	0					
	19	4	2	100.0				
	26	2	0					
Feb.	2	0	0					
	9	0	0					
	16	1	1		100.0			
	23	0	0					
March	2	0	0					
	9	0	0					
	16	0	0					
	23	12	1	100.0				
	30	130	48	91.5	4.2		4.2	
April	6	102	21	90.5	4.7		4.7	
	13	78	55	96.5	1.8		1.8	
	20	131	10	100.0				
	27	285	34	91.0			6.4	3.2
May	4	614	99	95.0	1.0		3.0	1.0
	11	1297	503	97.5	.4			2.2
	18	592	195	94.5		2.0	2.0	1.5
	25	1629	1013	96.0	.1	1.2	1.8	.9
June	1	2004	330	96.5	.9	.6	1.5	.6
	8	4554	697	97.0	.1	1.0	1.5	.3
July	6**	3945	1119	63.4	.4	7.5	28.2	.4
	13	4387	1543	93.5	.1	6.0	.3	.1
	20	4500	703	96.5		1.6	1.8	
	27	4482	1148	96.6	.9	1.9	1.5	
Aug.	3	3366	247	96.0	1.2	1.2	.8	.4
	10	5669	1041	98.4	.1	.7	.2	.4
	17	5749	2269	99.2	.1	.1	.1	.5
	24	3534	308	98.7		.7		.6
	31	4350	986	98.3	.2	.5	.2	.8
Sept.	7	6116	899	97.8	.1		.8	1.3
	14	4156	146	94.0	1.3	1.3	1.3	2.4
	21	2621	553	98.8	.2	.3	.2	.3
	28	1611	232	92.5		4.7	.4	1.7
Oct.	5	3597	212	99.0			.5	.5
	12	3371	160	97.5	.7		.7	.7
	19	1638	250	94.7	.4	2.8	1.6	.4
	26	620	89	97.8	1.1			1.1
Nov.	2	212	43	93.0	2.3			4.7
	9	173	17	100.0				
	16	18	12	100.0				

** Plant closed for repair June 15-30.

the majority of larvae escaping from the refuse were confined to the partially enclosed area under the apron conveyor. By sweeping this area daily, it was possible to collect and estimate the number of larvae migrating into this region each day. The number of larvae was calculated by taking a random sample from the sweepings, counting the number per sample, and computing the total number of larvae collected on the basis of the sample size and the amount of sweepings. The precision of this method was 6.00 ± 0.2 larvae per gram when 20.0 Kg of sweepings were sampled. This means that this counting procedure was quite precise. Table 10 shows the calculated number of larvae collected daily by sweeping under the apron conveyor, and also the number of larvae trapped in the larval sampling program for that same day. These values are then compared to determine the ratio of number trapped to the total number of larvae present. These ratios are recorded as percent trapped in Table 10 . The mean of these ratios was used to determine the population factor. This factor could be multiplied by the number of larvae trapped per day in the larval sampling program to estimate the total number of larvae escaping under the apron conveyor for that day. A mean of the percent trapped of 0.996% was calculated and recorded in Table 10 . A standard deviation of ±0.284 indicates this factor is reasonably reliable.

Larval migration from a pile of refuse could be expected to occur randomly in all directions. However, the construction of the

TABLE 10

DETERMINATION OF POPULATION ESTIMATOR

Sweepings (Kg)	Sample (Gm)	Larvae/ Sample	Number Larvae Collected	Number Larvae Trapped	Percent Trapped
19.05	976	1741	34,100	487	1.41
27.0	1894	2676	38,200	452	1.17
1.80	200	1500	13,500	114	0.84
18.4	642	3842	109,500	986	0.89
10.7	1076	6855	67,980	297	0.44
14.5	1009	4873	70,250	602	0.86
9.82	673	1993	29,100	238	0.82
17.4	862	1758	35,731	411	1.15
16.3	611	1796	45,851	490	1.07
22.2	885	3979	97,600	1294	1.31

$\bar{X} = 0.996 \pm .284$

receiving area and the practice of refuse handling influenced larval migration. Refuse is depoisted toward the east wall for storage during peak loading and is progressively removed from west to east by the front-end loader. Therefore, larvae migrating to the west are scraped into the receiving hopper and they do not survive. Likewise, northerly migration results in no survival since the ramp and paved areas provide no protective areas for pupation. Migration in an easterly direction provides protection and larvae occur in large numbers along the east wall of the receiving building. A wooden retaining wall, which is approximately three feet from the outer wall of the building, provides harborage to these migrating larvae. This area consequently produces many adult flies. It was difficult to sample and the number of larvae present was an approximation based on visual observations and numbers collected under the apron conveyor. This factor was estimated to be one-third of those under the apron conveyor for a given day.

From Table 10, it appears that in the larval sampling program approximately one percent of the larvae migrating into the apron conveyor area were trapped. Combining this factor with that calculated for the number of larvae migrating under the east wall of the receiving area, a population factor of 133 was obtained. This factor, when multiplied by the daily larval catch, should give some approximation of the number of larvae migrating from the refuse into the protected areas of the plant. For example, Table 9 shows that 6, 116 larvae were trapped the week of September 7. Multiplication by 133 gives an approximation of 813,400 larvae entering the plant during that one week period.

It appears that refuse should be cleared from the receiving area as quickly as possible to minimize the number of larvae which could otherwise migrate from it. It is expected that the number of larvae migrating from refuse is dependent in part on the length of time a pile of refuse remains in the receiving area. This hypothesis was tested by comparing the number of larvae collected under the apron conveyor during plant working hours with the number collected in the same area during off hours. This area was swept at the end of each working day and again just prior to the next working period. The number of larvae was calculated as previously described. Table 11 gives these results. The number of larvae collected during off hours when compared to the total number of larvae per day reveals that a reduction of more than one-third of the total larval population could be accomplished by clearing the receiving area of refuse at the end of each day.

Quite often refuse must remain in the receiving area and on the approach ramp for several days. When this occurs the number of migrating larvae increases considerably. These larvae migrate from the refuse falling from the ramp to the pavement below. On several occasions the number of larvae was so great that the pavement appeared white. On one such occasion, the pavement was swept clean and the larvae collected twelve hours later. Their number was estimated to be 60,000 larvae per day migrating from the ramp (east) alone.

TABLE 11

DETERMINATION OF NUMBER OF LARVAE ENTERING PLANT DURING OFF HOURS

Sweepings (Kg)	Sample (Gm)	Larvae Per Sample	Time* Interval	Number Larvae Collected	Total Daily Catch	Night Catch / Total Daily Catch (%)
7.22	725	3400	D	36,180		
2.95	351	3612	N	31,800	67,980	46.8
11.35	666	2508	D	42,700		
3.18	343	2971	N	27,550	70,250	39.2
7.95	360	794	D	17,500		
1.85	313	1961	N	11,600	29,100	39.8
16.8	722	1318	D	30,700		
0.65	140	995	N	4,620	35,320	13.0
16.3	611	1456	D	44,400		
3.35	283	2914	N	34,500	78,900	43.7
19.06	602	1992	D	63,200		
2.57	282	2834	N	25,800	88,900	29.1
						$\overline{X}$ = 35.7 ± 12.4

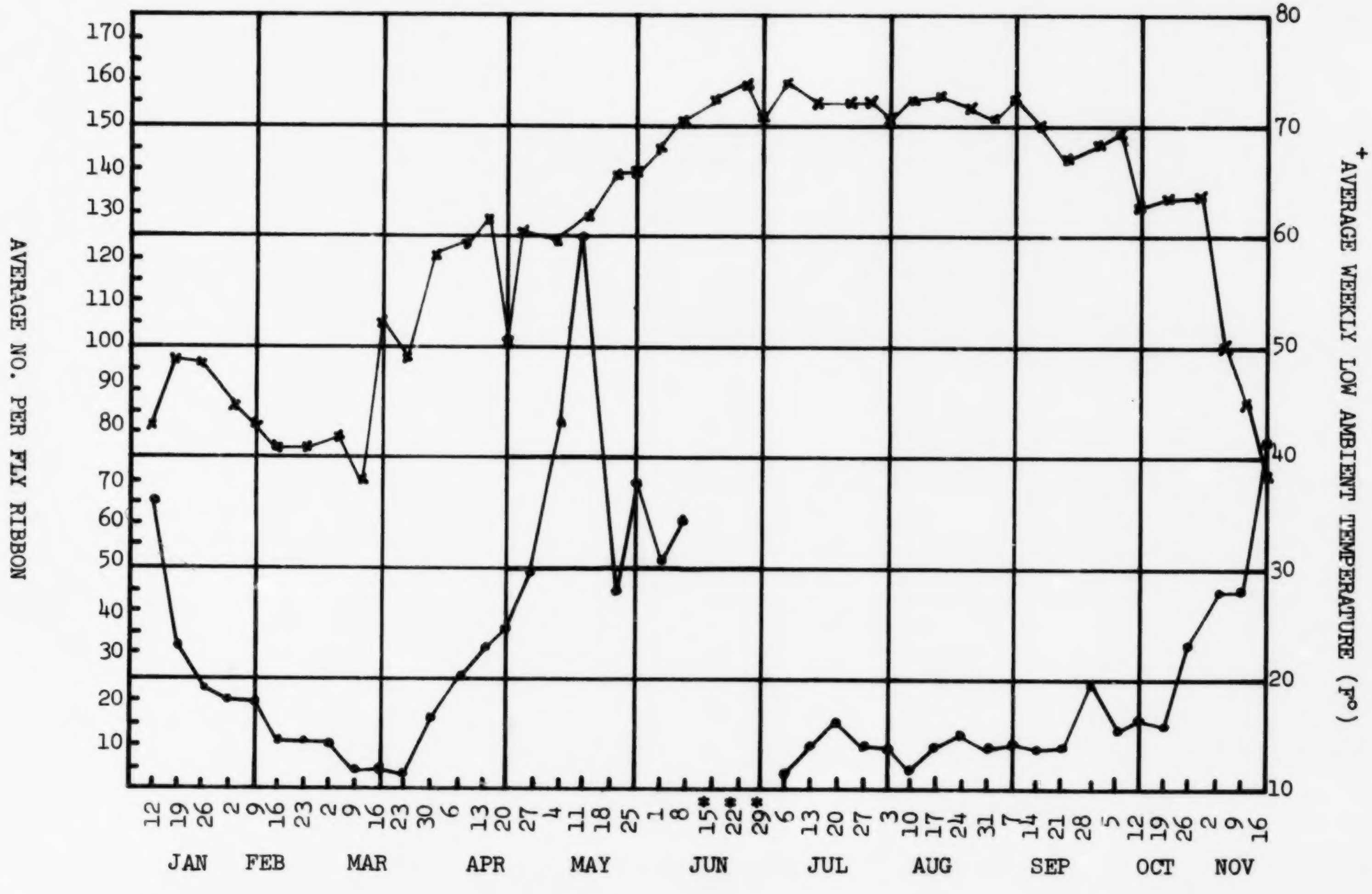
* D = 7:00 am - 6:15 pm
N = 6:15 pm - 7:00 am

The majority of larvae that migrate from the refuse are third instars and thus would require little external influence to develop into adults. This was demonstrated by a series of hatching studies. Larvae were placed into empty cups and other cups containing 25 gm of refuse debris. Both types contained 100 larvae each. The cups were covered with cloth, secured with a rubber band, and placed under the apron conveyor. Adult flies emerged in 8 - 10 days. Nine replications of each test gave a mean of 65.3% adult emergence from the cups with nothing added, and a mean of 88.8% adult emergence from the cups with debris. These data indicate that a minimum of 65% of the larvae which escape into the plant will emerge as adults and that if these larvae migrate to the large amount of debris present under the apron conveyor as many as 88.8% may be expected to emerge as adults. Thus, it is concluded that refuse should be cleared from the receiving area as quickly as possible. To do otherwise will encourage a fly problem.

b) Adult House Flies: It was initially assumed that the adult house fly population associated with the Compost Plant could be estimated by sampling the fly population above the digesters. A one-year study was initiated in January, 1969, to test the assumption. The methods and some results were given in the last interim report(6).

The survey showed that the fly population of the plant cannot be estimated from the fly population of the digesters. Figure 15 shows that the numbers of house flies do not always correlate with ambient temperatures. A sharp increase is recorded for the week of May 4. This may be partially attributed to the high moisture content of the compost that week. The plant was closed for repair the last three weeks of June and no samples could be taken. Upon resumption of operations, a sharp reduction was observed in numbers of flies caught. These low numbers continued well until the latter part of September when the daily catch began to increase. It is assumed that the low catch during the summer is due to high temperatures in the digester building where the air temperature often approached 110°F. Table 12 gives the average air temperature recorded on a hydrothermograph placed above the digesters for several one week periods. These data demonstrate more clearly the increasing fly population with decreasing average hourly temperature.

A large number of house flies was observed around the receiving area during the period of high indoor temperatures. This further demonstrates the unreliability of this sampling procedure during the summer months for estimating the total adult house fly population. However, the procedure does show population trends in the digester building. It may be useful in studies of fly breeding in the digester.



*Plant Closed for Repairs

+Temperature Data from Appendix Y

FIGURE 15
DENSITY INDICES OF ADULT HOUSE FLIES

TABLE 12

EFFECT OF TEMPERATURE ON NUMBER OF ADULT HOUSE FLIES IN THE DIGESTER BUILDING

	Air Temperature Of Digester Building			Average No. Flies Per Ribbon
Week Of:	Average Daily High	Average Daily Low	Average Hourly Temperature	
August 17	106.4	93.6	98.8	9.0
September 21	99.4	90.3	94.9	9.9
October 19	99.1	88.8	94.1	13.0
November 16	92.7	75.6	83.5	77.3

c) Adult Fly Control: An evaluation of several adult fly control procedures was undertaken during the summer of 1969. During the summer months, the majority of adult flies were observed around the receiving area and along the conveyor belt system, with relatively few observed above the digesters and other areas of the plant. Sweep net catches in these areas indicated the vast amjority of these flies were *Phaenicia* species. They were considered a nuisance to plant workers, in particular the pickers.

During, and 30 days prior to, this investigation, the plant's fly and roach control programs were suspended so that insecticide residuals would exert little or no effect on the tests. Six fly control procedures were evaluated. Another procedure was discussed but not evaluated. Effectiveness of the control procedures was determined by comparing fly counts made during the treatment period with counts made during a prior period of no treatment. The duration of pre-treatment control sampling was 7 days; subsequent control durations were 3 days. Treatment periods were alternated with control periods.

A 2' x 2' x 3' screen cone trap was chosen to sample the populations. This method gave 24 hour sampling and therefore was not subject to hourly variations. Fish heads were used to bait the traps because they were readily available and they attract most species of flies associated with refuse in this geographical area. Each trap was baited daily with one fish head which had "aged" for 24 hours at room temperature. Due to the operation of equipment during normal plant operations, traps could not be placed in the receiving area or along the conveyor belts. However, the area behind the receiving building proved suitable and two traps were placed in this area. Counting of flies was facilitated by placing the trap in a large plastic bag and killing the flies with ethyl acetate. The daily catch was recorded as a sum of the catches of the two traps.

Treatments treatment procedures are described as follows:

Sugar Bait: A 0.5% D.D.V.P. sugar bait, obtained commercially under the name Fly Bait, was applied at a rate of 400 grams per day. This bait was distributed along the conveyor belt system and under the apron conveyor for seven days.

Remove Larvae: The number of adult flies could be reduced by removing or killing the larvae which escape into the plant before they metamorphose to adults. The area under the apron conveyor was cleaned and swept daily to remove the larvae which had entered this area. This area was chosen because the majority of larvae enter the plant here and it is relatively easy to clean. The other main entrance for larvae, the east wall of the receiving area, was not cleaned because this area was not accessible. This method of control has some advantages. Because no pesticides are employed, there are no dangers involved in working with poisons and there is no problem of insect resistance. Because the transformation of larvae to adults takes approximately ten days under the existing conditions, the area would not need to be cleaned every day to reduce adult populations. It may be assumed that a weekly cleaning would be just as effective as daily cleaning.

Malt Bait: A 25% malt solution containing 1.0% D.D.V.P. was included in this study because malt bait was reported in the literature as being very effective at a Florida dump for the control of *Phaenicia*. Fifty ml were applied daily at four locations along the conveyor belts for a one-week period. This bait has several disadvantages: (1) it is not available commercially, but must be prepared by the user; (2) it must be stored under refrigeration; (3) it costs more than sugar bait; and (4) its syrupy consistency makes it inconvenient to work with.

Fogging: Fogging is not a highly recommended procedure for effective control of adult flies. However, because personnel at the Compost Plant at Johnson City, Tennessee, included fogging in their fly control program, this method was investigated. Fogging has several disadvantages: (1) it leaves no residue, thus killing only a percentage of the adult flies present at the time of fogging; (2) a high concentration of insecticide is necessary to kill adult flies, 5% for fogs as compared to 1 - 2% for liquids; (3) initial cost of fogger; and (4) the necessity of trained personnel.

It was observed that the adult blowflies, *Phaenicia*, left the plant buildings at dusk and roosted in the grass immediately surrounding the plant during the night. Because the flies were concentrated in this relatively small area, it was concluded that fogging the area at night would give the greatest chance of success. A 5.0% Fenthion in No. 2 fuel oil solution was distributed by a portable hot air swing fogger for three successive nights.

Residual Spray-Dimethoate: Because dimethoate is a widely used insecticide for the control of adult and immature house flies, it was chosen for this investigation. A 10% dimethoate solution was applied once with a hand sprayer at a rate of 2 gm/M^2 to the grassy areas surrounding the plant used as roosting sites for Phaenicia.

Residual Spray-Rabon: Rabon is an effective larvacide for house flies. A 10% Rabon solution was applied at a rate of 2 gm/M^2 in the same manner as described for dimethoate.

Kill Larvae: Killing larvae to reduce the number of adult flies could best be accomplished by the application of a chemical larvacide. Due to the large amounts of falling debris under the apron conveyor, the application of a larvacide would be ineffective and, therefore, was not attempted in this study.

Table 13 shows the effectiveness of each control procedure. The fly count reduction attributable to each treatment is obtained by comparing the mean daily count during treatment with the mean daily count during the previous control period. In addition to the usual pretreatment control, post treatment counts were used for the evaluation of the fogging and sprays to determine residual effects. The results follow:

TABLE 13

ADULT FLY COUNTS*

Day	Control	Sugar Bait[1]	Day	Control	Sweeping[2]
1	2343		1	1197	
2	2796		2	2316	
3	2268		3	1954	
4	979		4		856
5	1050		5	$\bar{X}$ = 1822	1055
6	3456		6		908
7	824		7		667
8		1178	8		353
9	$\bar{X}$ = 1959	875	9		1061
10		285	10		1775
11		596	11		1493
12		1041	12		1437
13		490	13		1315
14		107	14		988
		$\bar{X}$ = 653			$\bar{X}$ = 1083

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[1] 0.5% D.D.V.P. in sugar, daily

[2] Area under apron conveyor swept daily

* Number of flies caught per day

TABLE 13 (CONTINUED)

Day	Control	Malt Bait[3]	Day	Control	Fog[4]
1	1711		1	1967	
2	1397		2	1949	
3	1985		3	1826	
4	$\bar{X}$ = 1698	360	4	$\bar{X}$ = 1914	561
5		514	5		661
6		641	6		561
7		1245	7	627	$\bar{X}$ = 594
8		1467	8	1581	
9		597	9	1601	
10		1017	10	1811	
		$\bar{X}$ = 831		$\bar{X}$ = 1405	

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[3] 1.0% D.D.V.P. in 25% Malt solution, daily

[4] 5.0% Fenthion in No. 2 fuel oil, days 4 - 6

TABLE 13 (CONTINUED)

Day	Control	Dimethoate[5]	Day	Control	Rabon[6]
1	1437		1	1677	
2	1719		2	1170	
3	2241		3	1410	
4	$\bar{X}$ = 1799	28	4	$\bar{X}$ = 1419	1056
5		13	5		653
6		37	6		1251
7		18	7		734
8		64	8		949
9		49 $\bar{X}$ = 46*	9		781
10		112	10		1090
11		287			$\bar{X}$ = 931
12		170			
13		393			
14		811			
15		1256			
		$\bar{X}$ = 287			

---

[5] Dimethoate @ 2 gms./M^2, one application on day 4

[6] Rabon @ 2 gms./M^2, one application on day 4

* Mean of one week after treatment

Sugar Bait: This treatment reduced the adult fly population by 66.7 percent. The cost of one daily application was about $0.50 plus 0.1 man-hour.

Remove Larvae: This procedure reduced the adult fly population by 40.5 percent. About 4 man-hours per week were required.

Malt Bait: This treatment reduced the population by 51 percent. The cost of one daily application was about $0.70 plus 0.1 man-hour.

Fogging: This treatment reduced the population by 69 percent. The cost of one fogging was about $5.00 plus one man-hour. The post treatment counts show that the residual effect of fogging is minimal after 1 day.

Residual Spray-Dimethoate: Dimethoate reduced the population by 97.5 percent. The post treatment counts showed a residual effect for more than 10 days after the single application. The cost of one application was about $7.00 plus 0.5 man-hour.

Residual Spray-Rabon: This larvacide reduced the population by 34.4 percent. The cost of Rabon treatment was approximately the same as for dimethoate.

The study of adult fly control is not complete. Nevertheless it does show that adult flies can be controlled around waste treatment facilities. Furthermore, the study emphasized the need for background knowledge, both general and specific for the given plant, as a basis for fly control. Spraying with dimethoate resulted in the best fly control. The need for good housekeeping programs was also shown. Although sweeping resulted in only 40 percent reduction it must be emphasized that only a portion of the plant was swept. Therefore, good housekeeping practice is probably more beneficial than these data indicate.

d) Other Fly Studies: An investigation was undertaken to determine the influence of moisture and extent of waste decomposition on house fly breeding. In this study compost of various ages was tested at different moisture contents to determine the effects on rearing house flies. The compost used was taken from the digesters between 12 - 24 inches from the surface. The desired moistures were obtained by adding tap water. Fifty grams (dry weight) of compost was placed in a one quart waxed cup with 100 eggs or 100 larvae (48 hours old). The cup was then covered with a piece of cloth which was secured by a rubber band. CSMA rearing medium at 66 percent moisture was used as a control.

Table 14 shows the number of pupae formed. Forty-eight hour larvae will survive in compost of all ages and moisture contents tested. House fly eggs survived best in 60 - 75% moisture. The age of the compost also influenced survival. The final grind reduced survival considerably but still showed 8.5% survival in the finished product. Further tests are planned in this area. Another test is planned in which the amount of sludge will be varied to determine influence in breeding in the digesters and in the laboratory.

TABLE 14

INFLUENCE OF MOISTURE AND AGE OF COMPOST ON HOUSE FLY SURVIVAL

Average Number of Pupae per 100 Larvae (48 Hours Old)

Time Composted [1/] (Days)	Percent Moisture 30	45	60	75	90	Control
0	82.5	78.0	84.8	81.6	67.0	99.1
1	59.3	81.3	58.6	33.5	50.3	92.5
3	84.3	79.3	80.3	86.3	80.1	90.1
5	76.0	80.6	84.6	91.6	70.1	92.6
10	81.6	79.6	86.6	90.3	58.5	92.6
10 [2/]	82.8	86.6	89.0	90.5	80.3	92.6

Average Number of Pupae per 100 Eggs

Time Composted [1/] (Days)	Percent Moisture 30	45	60	75	90	Control
0	0	0.8	16.5	43.3	5.6	80.6
1	0	0	1.3	13.8	0	87.6
3	0	0	21.2	40.8	0.8	78.6
5	0	0	3.1	39.0	0.6	69.8
10	0	0	3.1	25.1	0.3	80.5
10 [2/]	0	0	0.3	8.5	0	88.3

[1/] Length of time in digester tanks

[2/] After passing through final grind (Finished Product)

A single test was performed to determine if larvae entering the plant in the refuse could survive the grinding process. Third instar larvae were passed through the grinder and some living larvae were recovered. During this period the primary grinder was not in operation and only the secondary grinder was in use. This experiment cannot be interpreted quantitatively, but it does show that some larvae will survive the grinding process. These larvae may proceed to the digesters where they may develop if conditions are suitable.

12. Public Health Aspects of Composting

The objective of the public health evaluation was to delineate possible health hazards associated with high-rate composting processes. Potential health hazards are created by pathogenic microorganisms in refuse and compost and those in aerosolized form in work areas. Potential health hazards also are created by arthropods and rodents which are attracted to wastes and are vectors of diseases afflicting man and animals. Control of arthropods and rodents was reported in Section H-11. Additional hazards include non-viable aerosolized matter which could cause lung diseases and noise which could damage the hearing of plant personnel. Methods for the assesment of public health hazards were presented in Sections E and F.

a) Microbiological Evaluation: The purpose of the microbiological evaluation was to determine whether microorganisms associated with refuse and compost constitute health hazards, real or potential. Health hazards to the consumer are inferred by the detection of certain microorganisms which indicate the presence of pathogens in the compost product. Health hazards to plant personnel are manifested by physical examinations and by the detection of pathogenic microorganisms in the air breathed by workers. The public health quality of compost was evaluated by periodic examination for fecal coliforms, Salmonellae, and by special die-off studies.

Fecal coliform bacteria were used as indicators of pathogenic microorganisms. The assumption was that the destruction of coliforms by composting would also indicate the destruction of pathogens. Consequently, the numbers of fecal coliforms in compost was compared with the numbers of the same organism in raw refuse. Table 15 shows the average fecal coliform indices in refuse and compost over an extensive period of time. Coliform bacteria readily survived in composting refuse. The length of treatment by composting varied from 3 - 10 days. As discussed in Section H-6 the survival of coliforms was more dependent on the moistening agent than on the length of treatment. When water was used to moisten raw ground refuse, the coliform population in the resulting compost remained stationary or increased relative to the original population. By contrast, when sewage sludge was used, the coliform population in the resulting compost decreased for the most part.

TABLE 15

AVERAGE COLIFORM INDICES

Period Sampled	Moistener	Raw Refuse	Number of Samples	Compost	Number of Samples
5-27-68 to 9-16-68	Water	4.1×10^{3}	18	2.7×10^{5}	10
6-5-68 to 6-26-68	Digested Sludge	1.7×10^{6}	20	4.4×10^{2}	14
5-27-68 to 9-16-68	Water	$1.5 \times 10^{6*}$	18	$2.5 \times 10^{6*}$	10
6-5-68 to 6-26-68	Digested Sludge	$6.0 \times 10^{6*}$	20	$7.0 \times 10^{3*}$	14
10-2-68 to 12-31-68	Digested Sludge	7.7×10^{7}	11	1.5×10^{8}	6
1-6-69 to 2-11-69	Digested Sludge	1.7×10^{8}	10	5.5×10^{6}	5
2-17-69 to 4-29-69	Water	1.1×10^{8}	15	2.0×10^{7}	14
5-5-69 to 12-1-69	Raw Sludge	2.5×10^{8}	32	4.8×10^{6}	28

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*Indicates total coliform indices; all other values are fecal coliform indices.

Regardless of the effect of the moistening agent the coliform bacteria survived the composting process. This might indicate that pathogenic microorganisms also survive composting, although this possibility was discounted in subsequent work.

Salmonella bacteria were also used as indicators of pathogen destruction. Indication of the destruction of pathogens is based on the same principle as that in the coliform method except that the Salmonellae were not determined quantitatively. Samples of raw refuse and compost were examined for the presence of Salmonella . A total of 144 samples of raw refuse, 101 samples of plant effluent compost, and 2 samples of old stockpiled compost were examined for the presence of Salmonella . This organism was found in three samples of raw refuse and in two samples of compost which was cured for an estimated duration of 1 year. It was never found in samples of compost which was subjected to digestion only. Digested sewage sludge was used for moistening refuse when Salmonella was detected in two samples of refuse. Raw sewage sludge was used when Salmonella was detected in one sample of refuse. No sludge had been added to refuse when it was processed a year prior to sampling for Salmonella in the resulting old compost. The finding of Salmonella in this old compost is inexplicable.

The meaningful use of Salmonella as an indicator of pathogen destruction by the stipulated method is very doubtful inasmuch as it was seldom found in raw refuse. Thus, the failure to find Salmonella in effluent compost does not indicate that it was killed during the composting process. Its use in another method whereby refuse is intentionally seeded with Salmonella could be meaningful.

Composting, besides accomplishing a satisfactory amount of waste stabilization, must also accomplish waste sanitation. This is particularly important when refuse is amended with raw sewage sludge. The destruction of pathogenic microorganisms would indicate that waste has been sanitized. However, it is extremely difficult to detect pathogenic organisms in solid wastes because of their presence in very small numbers and because the presence of other microorganisms in vast numbers obscures the pathogens. The detection of pathogens in compost would show that they survived the composting process or that they were reintroduced. Failure to detect pathogens in compost, on the other hand does not necessarily show that they were killed. Failure could mean that either the particular sample contained no pathogens or if it did, they might have been overgrown by other microorganisms during the duration of the test procedure. This suggested the use of an assay procedure for the detection of microorganisms which might indicate the presence of pathogenic microorganisms. The selected assay procedures will detect the indicator organisms in the presence of large numbers of extraneous organisms.

However, it is questionable whether the indicator organisms truly indicate the presence of pathogenic organisms. Furthermore, the detection of coliforms and *Salmonella* as indicators had doubtful meaning as discussed above.

Table 16 shows the plate counts before and after treatment for the various organisms tested. In general, the results show that high-rate composting has a pronounced adverse effect on the pathogenic bacteria evaluated under this study. *Escherichia coli*, a non-pathogenic bacterium, survived 12 days of composting. In only one experiment, in which *E. coli* was exposed for 4 days, was there any evidence that its population was decreased. The precision of this counting procedure is usually one order of magnitude. Thus, a population reduction in 12 days from 3.1×10^8 to 1.0×10^8 is not significant. It is interesting to note that whereas the population of *E. coli* remained stationary in 3 of 4 experiments, previous work showed that the numbers of coliforms were reduced when refuse was supplemented with sewage sludge. The coliform bacteria consists of a group of species of *Escherichia*, including *E. coli* and *Aerobacter*. Apparently, the reduction of coliforms is attributable to the reduction of species other than *E. coli* which remains approximately stationary.

Salmonella typhimurium was killed in one day when exposed to composting refuse. When incubated in the laboratory at 99°F in the

TABLE 16

EFFECT OF COMPOSTING ON EXTRINSIC MICROORGANISMS

Organism	Treatment Time (days)	Numbers of Organisms		Moisture		pH	
		Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
Escherichia coli	5	3.5×10^8	3.1×10^7				
E. coli	12	3.1×10^8	1.0×10^8				
E. coli	4	2.7×10^8	4.1×10^7	78.1	33.7	6.6	
E. coli	4	3.0×10^9	4.0×10^5	68.3	59.2	6.7	6.55
Salmonella typhimurium	4	2.2×10^6	0	61.8	48.4	6.6	6.4
S. typhimurium	2	1.9×10^9	0	72.7	64.1	6.7	6.05
S. typhimurium	1	7.0×10^6	0	65.9	58.8	6.55	5.8
Incubated at 99°F	1	7.0×10^6	5.4×10^6	65.9	60.9	6.55	6.05
S. paratyphi (B)	4	2.0×10^7	0	62.7	62.0	5.7	6.5
S. paratyphi (B)	1	3.9×10^5	1.0×10^5	57.3	61.9	6.75	5.65
Incubated at 99°F	1	3.9×10^5	7.8×10^6	57.3	61.5	6.75	5.85
S. paratyphi (B)							
93 - 108°F	1	7.5×10^5	8.5×10^6	64.9	62.1	5.95	5.8
93 - 126°F	4	8.5×10^6	0	64.9	46.1	5.95	6.65
93 - 131°F	1	7.6×10^6	0	64.9	61.9	5.95	6.3

TABLE 16
(Continued)

EFFECT OF COMPOSTING ON EXTRINSIC MICROORGANISMS

Organism	Treatment Time (days)	Numbers of Organisms		Moisture		pH	
		Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
S. enteritidis	2	9.0×10^7	0	71.3	65.4	6.62	6.5
S. enteritidis	1	1.4×10^5	0	65.5	56.4	6.08	5.75
Incubated at 99°F	1	1.4×10^5	7.5×10^6	65.5	63.7	6.08	5.85
Bacillus stearothermophilus vegatative cells	1	2.0×10^6	0	70.5	68.6	5.85	6.51
	5	2.0×10^6	0	70.5	63.7	5.85	6.65
B. stearothermophilus spores	1	1.4×10^8	4.0×10^5	62.0	58.0	5.65	5.75
B. stearothermophilus vegatative cells in a culture tube of broth	1	6.0×10^{10}	0				
B. stearothermophilus spores	1	1.2×10^7	1.0×10^4	66.9	62.0	5.45	6.55
	2	1.2×10^7	6.0×10^4	66.9	59.1	5.45	6.55

presence of ground refuse the population remained stationary. S. paratyphi was killed in one day if a temperature of approximately 131°F is attained.

Bacillus stearothermophilus is one of the most heat tolerant organisms known to exist. It is frequently used to test the operation of autoclaves and other sterilizing equipment. Vegetative cells of this organism were readily killed in one day in a composting environment, although a population of spores were not completely reduced in two days.

On the basis of these data it appears that high rate composting is likely to kill pathogenic organisms in two days. It must be realized that both the temperature and the duration of time that organisms are exposed to heat are important factors in producing thermal death. Therefore, refuse which is not heated adequately will harbor living pathogens. It was not an objective of this work to develop all inclusive time and temperature relationships for thermal death since this has been investigated by others. However, it does appear that high rate composting sanitizes refuse more quickly than windrow composing.

b) Airborne Particulate Matter: The air in dusty areas of the plant was sampled for particulate matter as an indicator of potential public health hazards. Particulate matter was determined with both a standard high volume sampler for total particulates and with an Andersen Sampler for particle size distribution. Both viable and non-viable particulate matter was determined with the Andersen Sampler.

An 8 x 10" Fiberglas filter was used in the high volume sampler which is 99% effective in removing particles ranging in size from 0.1 micron and larger. The flow rate of air through the instrument was 39.2 cubic ft. per minute. The instrument was placed in the plant midway between the primary and secondary grinders. It was operated for 4 3/4 hrs. in the afternoon of October 17, 1969. Total particulate matter was 3793 micrograms per cubic meter of air ($\mu g/m^3$). This value is extremely high as compared with acceptable ambient air values reported in Air Quality Criteria for Particulate Matter (issued February, 1969, by the National Air Pollution Control Administration). Adverse health effects were noted when the annual mean level of particulate matter exceeded 80 $\mu g/m^3$, visibility reduction to about 5 miles was observed at 150 $\mu g/m^3$, and adverse effects on materials were observed at an annual mean exceeding 60 $\mu g/m^3$.

Air was sampled for viable particles with a Model 0604 Andersen Sampler (Andersen Samplers and Consulting Service, 1074 Ash Avenue, Provo, Utah, 84601). The sampler was used at various areas in the compost plant where suspended dust was obvious. The sampler separated microorganisms into six categories according to size and aerodynamic properties. The microorganisms were impinged on the surfaces of agar contained in six Petri dishes. Tryptone-Glucose-Extract Agar was used for the detection of general airborne microorganisms, Potato Dextrose Agar for fungi, and Brain-Heart Infusion

Agar for pathogenic bacteria. The agar-impinged organisms were incubated for 18 - 24 hours until small colonies developed, at which time they were counted.

Numbers of viable particles collected from the air in various areas on the plant premises are reported in Table 17. The data clearly show that two areas in the plant contain large numbers of aerosolized microorganisms at the time of sampling. By comparison, the laboratory air was relatively clean. The data indicate the presence of broad groups of microorganisms such as bacteria and fungi, but do not indicate pathogenicity. According to the manufacturer of sampler, any particle 5 microns or less in diameter can penetrate the lungs and is therefore hazardous.

Particle size distribution (weights of particles of various sizes) was determined at two locations in the plant with the Anderson sampler. Two determinations were made on September 9, 1969, at the operators platform. Duration of sampling was one hour in the morning and 30 minutes in the afternoon. One determination was made on September 9, 1969, at the picking table. The duration of that sampling was one hour. Particle weights were determined by weighing the glass collection plates before and after exposure and by subtracting the two values.

Table 18 shows that both plant areas are extremely dusty. It is generally recognized that particles having a diameter of 5μ or less can penetrate the lungs. Lung penetrability increases as particle

Agar for pathogenic bacteria. The agar-impinged organisms were incubated for 18 - 24 hours until small colonies developed, at which time they were counted.

Numbers of viable particles collected from the air in various areas on the plant premises are reported in Table 17. The data clearly show that two areas in the plant contain large numbers of aerosolized microorganisms at the time of sampling. By comparison, the laboratory air was relatively clean. The data indicate the presence of broad groups of microorganisms such as bacteria and fungi, but do not indicate pathogenicity. According to the manufacturer of sampler, any particle 5 microns or less in diameter can penetrate the lungs and is therefore hazardous.

Particle size distribution (weights of particles of various sizes) was determined at two locations in the plant with the Anderson sampler. Two determinations were made on September 8, 1969, at the operators platform. Duration of sampling was one hour in the morning and 30 minutes in the afternoon. One determination was made on September 9, 1969, at the picking table. The duration of that sampling was one hour. Particle weights were determined by weighing the glass collection plates before and after exposure and by subtracting the two values.

Table 18 shows that both plant areas are extremely dusty. It is generally recognized that particles having a diameter of 5μ or less can penetrate the lungs. Lung penetrability increases as particle

VIABLE AEROSOLIZED ORGANISMS[1]

			AREA SAMPLED								
			LAB		CONTROL CONSOLE			OSCILLATING CONVEYOR			
	Stage Number	Particle Size Range, Microns[3]	PDA[4]	TGEA[5]	PDA	TGEA	BHI[6]	TGEA	TGEA	TGEA	BHI
[2] Non-hazardous Range No Lung Penetration	1	8-15+	2	4	335	∞	659	43	—[7]	--	437
	2	5-11	6	31	144	∞	364	28	199	--	223
	3	3- 6	2	3	204	816	423	13	108	535	78
Hazardous Range Lung Penetration	4	2-3.5	4	15	188	1198	563	12	125	292	64
	5	1- 2	1	1	67	367	248	14	8	319	34
	6	1 and less	0	0	24	25	21	--	6	73	3

1. All data represent numbers of organisms per cubic foot of air
2. Claimed by Andersen Samplers and Consulting Service
3. Each stage includes 95% or more of the particles collected on that stage
4. Potato Dextrose Agar
5. Tryptone-Glucose Extract Agar
6. Brain Heart Infusion Agar
7. Data obscured by spreading colonies

TABLE 17

TABLE 18

NON-VIABLE AEROSOLIZED PARTICLES

Stage Number	Particle Size Range, microns	Particle Weights, $\mu g/m^3$, at Various Locations		
		Operators Platform, A.M.	Operators Platform, P.M.	Picking Table
1	9.2 and larger	1236	939.4	233
2	5.5 - 9.2	409.6	586.2	176.6
3	3.3 - 5.5	293.1	469.7	56.5
4	2.0 - 3.3	116.5	293.1	116.5
5	1.0 - 2.0	176.6	586.2	469.7
6	up to 1.0	353.1	586.2	56.5
Total		2584.9	3460.8	1108.8

size decreases from 5μ. Thus, particles collected on stages 3 - 6 are especially hazardous to exposed personnel. All values exceed the air quality criteria set by the National Air Pollution Control Administration (NAPCA). Most values greatly exceed these criteria.

Even though only a few analyses were made, one can readily see that the atmosphere near the grinders and the picking table is very dusty. Thus, even though the reported values might be 2 - 3 times higher than typical values, a definite hazard is still manifested. Data showing particulate matter in ambient air greatly exceed the NAPCA air quality criteria for maximum tolerable levels. Therefore, it is concluded that the atmosphere surrounding the primary and secondary grinders, the operator's platform, and the picking table is a potential hazard to the health and well-being of exposed personnel.

c) Parasitological Analysis of Compost: The presence in compost of viable eggs and mature forms of intestinal parasites would be evidence of insufficiently sanitized compost. Samples of sewage sludge, ground refuse, and compost were examined for intestinal parasites. Samples were taken in October, 1968, and in January, March, and October, 1968. They were sent to the Division of Research and Development, Solid Waste Office for examination.

As expected, sewage sludge either raw or digested contained intestinal parasites. Raw ground refuse was never found to contain eggs or mature forms, but one sample of digested refuse which was not moistened with sludge did contain rhabditiform larvae of hookworm or Strongyloides. Two ova of Hymenolepsis diminuta were found in one sample of digested refuse which had been supplemented with digested sludge. It must be emphasized that the analytical methods used in the performance of this work could not be distinguished between living and dead parasites. However, it is possible to distinguish between intact and decomposed organisms. It was assumed, therefore, that the intact organisms survived composting and decomposed organisms did not.

It was strongly indicated that the curing of compost in windrows killed intestinal parasites. Ova of Ascaris lumbricoides and Hymenolepsis diminuta and hookworms or Strongyloides larvae were found in compost which had cured in windrows for up to 3 months. However, none of the windrows were turned or otherwise managed. Those parasites that apparently survived 3 months of curing were found in compost which was collected within 3 inches of the surface. Although it is not known what effect windrow turning would have on parasite survival, it is likely that survival time would be reduced.

d) Physical Examinations: All plant workmen and most administrative personnel were given periodic physical examinations to determine clinical manifestations associated with exposure to solid wastes. The plan was to have each person examined before any exposure to solid wastes and then periodically thereafter. Comparison of the findings before and after exposure might reveal certain health hazards. However, rapid personnel turnover and inherent shortcomings of clinical studies made it difficult to make a good comparison.

Seventeen employees were given complete physical examinations. Twelve employees were reexamined about one year later. No changes were noted in their general state of health. Thirty Mantoux skin tests were given; three were positive indicating that they were exposed to tuberculosis. One of the positive reactors gave a positive reaction prior to any exposure to solid wastes. It is not known whether the other two positive reactors were previously positive. All of the seventeen histoplasmin skin tests were negative.

The accident record attributable to solid waste handling has been good with two individual exceptions. Table 19 shows the frequency and types of injuries.

e) Noise: Sound level determinations were made on two occasions in the vicinity of all pieces of heavy equipment in the plant. The surveys were made when the Jay Centriblast shredder was in use and then again after it was replaced with a Williams shredder. Detailed results were given in two previous reports(2,6). In summary, the most hazardous piece of machinery regarding noise is the primary shredder. The hazard results not only from the high level of noise generated, but also from the close location of the laborers to this

TABLE 19

SUMMARY OF WORK INJURIES

Date of Injury	Time Lost	Age of Employee	Job Classification	Type of Injury
6/25/68	158 days	40	Maintenance	Fractured bone in arm
11/5/68	39 days	21	Grinder Operator	Cut tendons in foot
11/19/68	3 days	47	Welder	Fractured bone in toe
7/24/69	1 day	17	Salvage Laborer	Twisted knee
8/8/69	1 day	33	Laborer	Sprained ankel
10/1/69	1 day	19	Truck Driver	Cut hand

Nineteen minor injuries such as cuts and bruises - No lost time.

Total days lost because of injury	-	203
Total work days, approximate	-	41,600
Percent of work time lost, approximate	-	0.48

source of noise. These laborers are exposed to sound levels of 100 - 102 dbA. The maximum exposure time to this intensity allowed by the Safety and Health Standards for the Walsh - Healey Act is 1.5 - 2.0 hours per day. Because these laborers are exposed for longer periods of time, they were issued ear plugs for their protection.

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